Senior Design Report
for
ECE 477 – Fall 2009

submitted by
Prof. David G. Meyer
December 22, 2009

PURDUE
UNIVERSITY
School of Electrical & Computer Engineering

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Course Description

Digital Systems Senior Design Project (ECE 477) is a structured approach to the development and integration of embedded microcontroller hardware and software that provides senior-level students with significant design experience applying microcontrollers to a wide range of embedded systems (e.g., instrumentation, process control, telecommunications, intelligent devices, etc.). The primary objective is to provide practical experience developing integrated hardware and software for embedded microcontroller systems in an environment that models one which students will most likely encounter in industry.

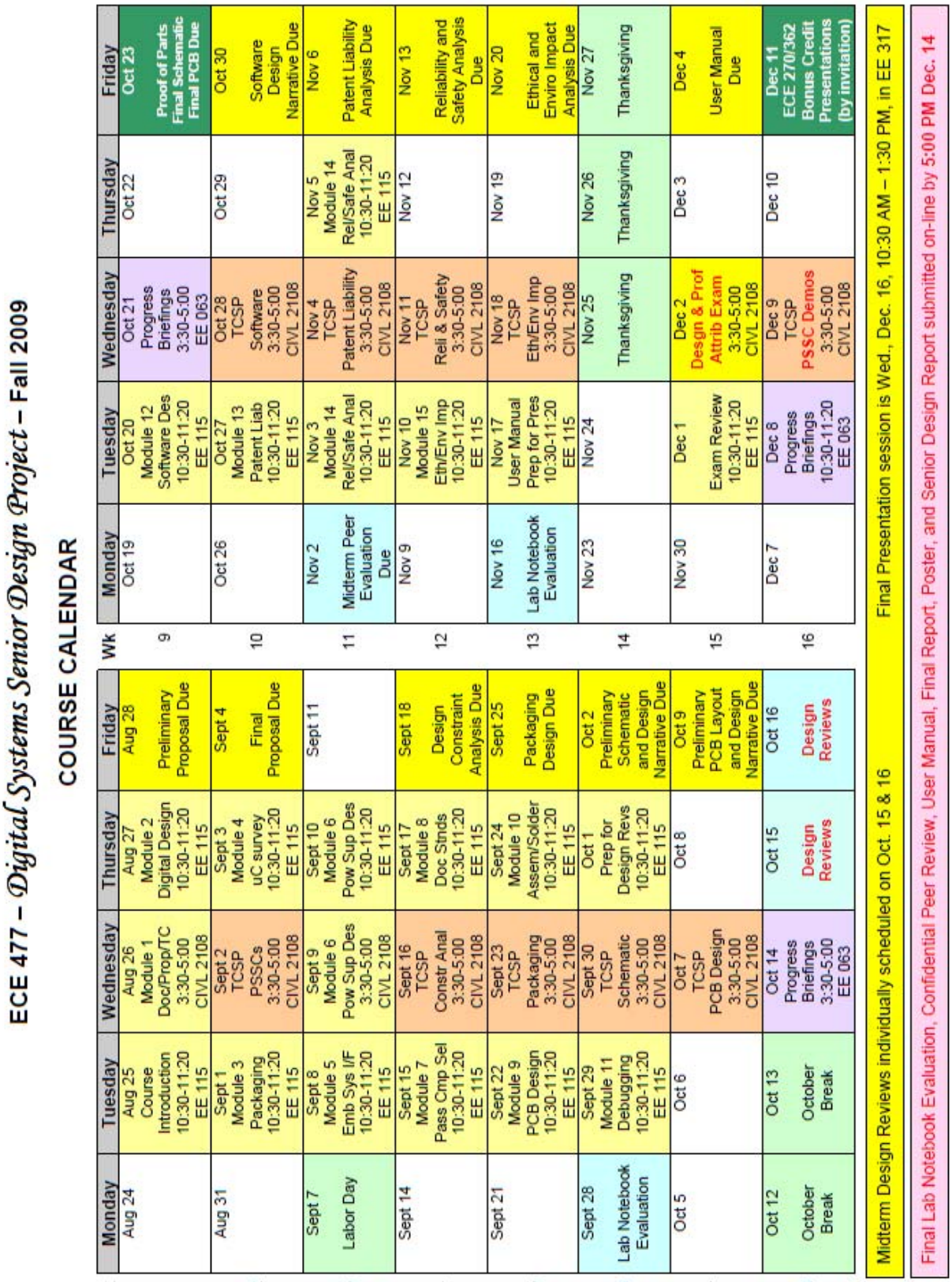
One of the unique features of this course is that each team gets to choose their own specific project (subject to some general constraints) and define specific success criteria germane to that project. In general, this approach to senior design provides students with a sense of project ownership as well as heightened motivation to achieve functionality.

Course web site: `https://engineering.purdue.edu/ece477`

Course Staff

Name	*Title / Role*	*E-mail Address*
Prof. David Meyer	Faculty / Project Advisor	meyer@purdue.edu
Dr. Mark Johnson	Faculty / Project Advisor	mcjohnso@purdue.edu
David Collins	Teaching Assistant / Project Consultant	dpcollin@purdue.edu
Charles Barnett	Lab Technical Support	barnettc@purdue.edu

Lecture Schedule / Course Calendar



ECE 477 – *Digital Systems Senior Design Project* – Fall 2009

COURSE CALENDAR

Wk	Monday	Tuesday	Wednesday	Thursday	Friday
1	Aug 24	Aug 25 Course Introduction 10:30-11:20 EE 115	Aug 26 Module 1 Doc/Prop/TC 3:30-5:00 CIVL 2108	Aug 27 Module 2 Digital Design 10:30-11:20 EE 115	Aug 28 Preliminary Proposal Due
2	Aug 31	Sept 1 Module 3 Packaging 10:30-11:20 EE 115	Sept 2 TCSP PSSCs 3:30-5:00 CIVL 2108	Sept 3 Module 4 uC survey 10:30-11:20 EE 115	Sept 4 Final Proposal Due
3	Sept 7 Labor Day	Sept 8 Module 5 Emb Sys I/F 10:30-11:20 EE 115	Sept 9 Module 6 Pow Sup Des 3:30-5:00 CIVL 2108	Sept 10 Module 6 Pow Sup Des 10:30-11:20 EE 115	Sept 11
4	Sept 14	Sept 15 Module 7 Pass Cmp Sel 10:30-11:20 EE 115	Sept 16 TCSP Constr Anal 3:30-5:00 CIVL 2108	Sept 17 Module 8 Doc Stnds 10:30-11:20 EE 115	Sept 18 Design Constraint Analysis Due
5	Sept 21	Sept 22 Module 9 PCB Design 10:30-11:20 EE 115	Sept 23 TCSP Packaging 3:30-5:00 CIVL 2108	Sept 24 Module 10 Assem/Solder 10:30-11:20 EE 115	Sept 25 Packaging Design Due
6	Sept 28 Lab Notebook Evaluation	Sept 29 Module 11 Debugging 10:30-11:20 EE 115	Sept 30 TCSP Schematic 3:30-5:00 CIVL 2108	Oct 1 Prep for Design Revs 10:30-11:20 EE 115	Oct 2 Preliminary Schematic and Design Narrative Due
7	Oct 5	Oct 6	Oct 7 TCSP PCB Design 3:30-5:00 CIVL 2108	Oct 8	Oct 9 Preliminary PCB Layout and Design Narrative Due
8	Oct 12 October Break	Oct 13 October Break	Oct 14 Progress Briefings 3:30-5:00 EE 063	Oct 15 Design Reviews	Oct 16 Design Reviews
9	Oct 19	Oct 20 Module 12 Software Des 10:30-11:20 EE 115	Oct 21 Progress Briefings 3:30-5:00 EE 063	Oct 22	Oct 23 Proof of Parts Final Schematic Final PCB Due
10	Oct 26	Oct 27 Module 13 Patent Liab 10:30-11:20 EE 115	Oct 28 TCSP Software 3:30-5:00 CIVL 2108	Oct 29	Oct 30 Software Design Narrative Due
11	Nov 2 Midterm Peer Evaluation Due	Nov 3 Module 14 Rel/Safe Anal 10:30-11:20 EE 115	Nov 4 TCSP Patent Liability 3:30-5:00 CIVL 2108	Nov 5 Module 14 Rel/Safe Anal 10:30-11:20 EE 115	Nov 6 Patent Liability Analysis Due
12	Nov 9	Nov 10 Module 15 Eth/Env Imp 10:30-11:20 EE 115	Nov 11 TCSP Reli & Safety 3:30-5:00 CIVL 2108	Nov 12	Nov 13 Reliability and Safety Analysis Due
13	Nov 16 Lab Notebook Evaluation	Nov 17 User Manual Prep for Pres 10:30-11:20 EE 115	Nov 18 TCSP Eth/Env Imp 3:30-5:00 CIVL 2108	Nov 19	Nov 20 Ethical and Enviro Impact Analysis Due
14	Nov 23	Nov 24	Nov 25 Thanksgiving	Nov 26 Thanksgiving	Nov 27 Thanksgiving
15	Nov 30	Dec 1 Exam Review 10:30-11:20 EE 115	Dec 2 Design & Prof Attrib Exam 3:30-5:00 CIVL 2108	Dec 3	Dec 4 User Manual Due
16	Dec 7	Dec 8 Progress Briefings 10:30-11:20 EE 063	Dec 9 TCSP PSSC Demos 3:30-5:00 CIVL 2108	Dec 10	Dec 11 ECE 270/362 Bonus Credit Presentations (by invitation)

Midterm Design Reviews individually scheduled on Oct. 15 & 16

Final Presentation session is Wed., Dec. 16, 10:30 AM – 1:30 PM, in EE 317

Final Lab Notebook Evaluation, Confidential Peer Review, User Manual, Final Report, Poster, and Senior Design Report submitted on-line by 5:00 PM Dec. 14

Design Project Specifications / Requirements

Work on the design project is to be completed in teams of four students. The design project topic is flexible, and each group is encouraged to pick a product that uses the strengths and interest areas of their group members. The design must have the following components:

- **Microprocessor:** To help make the project tractable, microprocessor choices will be limited to 68HC12, PIC, Rabbit, and Atmel variants. Development tools are readily available in lab to support these devices. Further, the devices themselves are relatively low cost and readily available.
- **Interface to Something:** Your embedded system must interface to some other device or devices. It could be a computer, or it could be some embedded device such as a Palm Pilot, telephone line, TV, etc. Some interface standards that could be used are: serial to a computer, parallel to a computer, Universal Serial Bus (USB), Firewire, Ethernet, Infrared (IR), Radio Frequency (RF), etc. This requirement has a large amount of freedom. To help with some of the more complex interfaces such as Ethernet, USB, or Firewire there are dedicated chips which encapsulate the lowest layers of the interface. This makes using these interfaces easier to handle but not necessarily trivial. Be sure to investigate the interface(s) you wish to utilize and make a reasonable choice. (NOTE: *Interfaces involving A.C. line current require special permission – see the instructor for details.*)
- **Custom printed circuit board:** Through the process of the design, each group will be required to draw a detailed schematic. From the schematic, a two-layer (maximum) printed circuit board will be created. Board etching will be processed by the ECE Department (the first one is "free", but any subsequent iterations are the team's responsibility). The team is then responsible for populating the board (solder the parts on the board), and for completing the final stages of debugging and testing on their custom board.
- **Be of personal interest to at least two team member:** It is very difficult to devote the time and energy required to successfully complete a major design project in which you and/or your team members have no personal interest. There are *lots* of possibilities, ranging from toys and games to "useful and socially redeeming" household items, like audio signal processors and security systems.
- **Be tractable:** You should have a "basic idea" of how to implement your project, and the relative hardware/software complexity involved. For example, you should not design an "internet appliance" if you have no idea how TCP/IP works. Also, plan to use parts that are reasonably priced, have reasonable footprints, and are *readily available*. Be cognizant of the prototyping limitations associated with surface mount components.
- **Be neatly packaged:** The finished project should be packaged in a reasonably neat, physical sound, environmentally safe fashion. Complete specification and CAD layout of the packaging represents one of the project design components.
- **Not involve a significant amount of "physical" construction:** The primary objective of the project is to learn more about *digital system* design, not mechanical engineering! Therefore, most of the design work for this project should involve digital hardware and software.

Project Proposal: Each group should submit a proposal outlining their design project idea. This proposal should not be wordy or lengthy. It should include your design objectives, design/functionality overview, and project success criteria. The five success criteria common to all projects include the following:

- Create a bill of materials and order/sample all parts needed for the design
- Develop a complete, accurate, readable schematic of the design
- Complete a layout and etch a printed circuit board
- Populate and debug the design on a custom printed circuit board
- Package the finished product and demonstrate its functionality

In addition to the success criteria listed above, a set of **five significant** *project-specific* success criteria should be specified. The degree to which these success criteria are achieved will constitute one component of your team's grade.

Forms for the preliminary and final versions of your team's project proposal are available on the course web site. Use these skeleton files to create your own proposal. Note that the proposal should also include assignment of each team member to one of the design components as well as to one of the professional components of the project.

Group Account and Team Webpage: Each team will be assigned an ECN group account to use as a repository for all their project documentation and for hosting a password-protected team web page. The team web page should contain datasheets for all components utilized, the schematic, board layout, software listings, interim reports, presentation slides, etc. It should also contain the individual lab notebooks for each team member as well as the progress reports (prepared in advance of the weekly progress briefings) for each team member. At the end of the semester, each team must submit a CD-ROM archive of the group account.

Design Review: Part way through the design process, there will be a formal design review. This is a critical part of the design process. In industry, this phase of the design process can often make or break your project. A good design review is one where a design is actively discussed and engineers present concur with the current or amended design. The design review is in some cases the last chance to catch errors before the design is frozen, boards are etched, and hardware is purchased. *A friend is not someone who rubber-stamps a design, but rather one who actively challenges the design to confirm the design is correct.*

Approach the design review from a top-down, bottom-up perspective. First, present a block diagram of your design and explain the functional units. Then drop to the bottom level and explain your design at a schematic level. Be prepared to justify every piece of the design; a perfectly valid answer, however, is applying the recommended circuit from an application note. If you do use a circuit from an application note, have the documentation on hand and be able to produce it. *Your grade for the design review will not be based on the number of errors identified in your design.* The best engineers make mistakes, and the purpose of the design review is to *catch them* rather than spend *hours of debugging later* to find them. The design review will be graded primarily on how well the group understands their design and the professionalism with which they present it.

To facilitate the design review process, the class will be split into subgroups that will meet at individually scheduled times. Both the presenters and the assigned reviewers will be evaluated.

Design Project Milestones

Each group is responsible for setting and adhering to their own schedule; however, there are several important milestones, as listed in the table below. Always "expect the unexpected" and allow for some buffer in your schedule. *Budget your time.* With proper budgeting, senior design can be a very rewarding and pleasant experience.

See course schedule for homework due dates.

Week	*Milestone*
1	Formulate project ideas Preliminary project proposal due
2	Research parts, create initial block diagram and initial BOM Final project proposal due
3	Order/sample parts, review/learn OrCad *Capture* and *Layout*
4	Create detailed BOM (including resistors, capacitors, etc.)
5	Draw preliminary schematic Prototype interface circuits
6	Finalize schematic Begin PCB layout Begin prototyping software with EVB/prototype
7	Finalize PCB layout for Design Review Continue software development Prepare for Design Review
8	Continue software development **DESIGN REVIEWS**
9	Incorporate changes/comments from Design Review **Proof-of-Parts due** **Final schematic due** **PCB file submission due**
10	Continue software development on EVB
11	PCBs arrive - begin populating/testing
11-15	Test PCB section-by-section as parts are added, porting software as you go - *add functions one-by-one so you know what it was that "broke" your code or your board when things stop working*
16	**PSSC Demos** Prepare for Final Presentation
Finals	**FINAL PRESENTATIONS**

Course Outcomes and Assessment Procedures

In order to successfully fulfill the course requirements and receive a passing grade, each student is expected to demonstrate the following outcomes:

(i) an ability to apply knowledge obtained in earlier coursework and to obtain new knowledge necessary to design and test a microcontroller-based digital system
(ii) an understanding of the engineering design process
(iii) an ability to function on a multidisciplinary team
(iv) an awareness of professional and ethical responsibility
(v) an ability to communicate effectively, in both oral and written form

The following instruments will be used to assess the extent to which these outcomes are demonstrated (the forms used to "score" each item are available on the course web site):

Outcome	*Evaluation Instruments Used*
(i)	Design Component Homework
(ii)	Individual Lab Notebooks
(iii)	Success Criteria Satisfaction (general *and* project-specific)
(iv)	Professional Component Homework
(v)	Formal Design Review, Final Presentation, and Final Report

Students must demonstrate basic competency in ***all*** the course outcomes, listed above, in order to receive a passing grade. Demonstration of Outcome (i) will be based on the satisfaction of the design component homework, for which a minimum score of **60%** will be required to establish basic competency. Demonstration of Outcome (ii) will be based on the individual lab notebook, for which a minimum score of **60%** will be required to establish basic competency. Demonstration of Outcome (iii) will be based on satisfaction of the **100%** of the general success criteria and a minimum of **60%** (3 out of 5) of the project-specific success criteria. Demonstration of Outcome (iv) will be based on the professional component homework, for which a minimum score of **60%** will be required on the final evaluation to establish basic competency. Demonstration of Outcome (v) will be based on the Design Review, the Final Presentation, and the Final Report. A minimum score of **60%** on the Design Review and a minimum score of **60%** on the Final Report and a minimum score of **60%** on the Final Presentation will be required to establish basic competency.

Since *senior design* is essentially a "mastery" style course, students who fail to satisfy all outcomes but who are otherwise passing (based on their NWP) will be given a grade of "I" (incomplete). The grade of "I" may subsequently be improved upon successful satisfaction of all outcome deficiencies. If outcome deficiencies are not satisfied by the prescribed deadline, the grade of "I" will revert to a grade of "F".

Course Grade Determination

Several "homeworks" will be assigned related to key stages of the design project. Some of the assignments will be completed as a team (1, 2, 7, 13, 15, 16, 17), two will be completed individually (8 and 14), and some will be completed by a selected team member (one from the set {4, 5, 6, 9} and one from the set {3, 10, 11, 12}).

1. Team Building and Project Idea
2. Project Proposal
3. Design Constraint Analysis and Component Selection Rationale
4. Packaging Specifications and Design
5. Hardware Design Narrative/Preliminary Schematic
6. PCB Design Narrative/Preliminary PCB Layout
7. PCB Submission, Final Schematic, and Parts Acquisition/Fit
8. Peer Review – Midterm
9. Software Design Narrative, and Documentation
10. Patent Liability Analysis
11. Reliability and Safety Analysis
12. Ethical/Environmental Impact Analysis
13. User Manual
14. Peer Review – Final
15. Senior Design Report
16. Final Report & Archive CD
17. Poster

Grade Determination: Your course grade will be based on team effort and your contributions:

TEAM COMPONENTS (40% of total) distribution of team component:		**INDIVIDUAL COMPONENTS (60% of tot.) distribution of individual component**	
Project Success Criteria Satisfaction*	20%	Laboratory Design Notebook*	20%
Design Review*	15%	Design Component Report*	15%
Final Presentation*	15%	Professional Component Report*	15%
Final Report*	15%	Significance of Individual Contribution	15%
Final PCB, Schematic, and Parts Fit	10%	Design and Professional Attribute Exam	15%
System Integration and Packaging	10%	Class Participation / Clicker Exercises	10%
User Manual	5%	Peer Evaluations of Presentations (2)	5%
Senior Design Report	5%	Confidential Peer Reviews (2)	5%
Poster	5%	* items directly related to outcome assessment	

Your **R**aw **W**eighted **P**ercentage (RWP) will be calculated based on the weights, above, and then "curved" (i.e., mean-shifted) with respect to the upper percentile of the class to obtain a **N**ormalized **W**eighted **P**ercentage (NWP). Equal-width cutoffs will then be applied based on the **W**indowed **S**tandard **D**eviation (WSD) of the raw class scores; the minimum **C**utoff **W**idth **F**actor (CWF) used will be 10 (i.e., the nominal cutoffs for A-B-C-D will be 90-80-70-60, respectively). Before final grades are assigned, the course instructor will carefully examine all "borderline" cases (i.e., NWP within 0.5% of cutoff). Once grades are assigned, they are **FINAL** and WILL NOT be changed. Note that **all** course outcomes must be demonstrated in order to receive a passing grade for the course.

Course Assessment Report

Course: ECE 477 **Submitted by:** D. G . Meyer
Term: Fall 2009 **Course PIC:** D. G. Meyer

1. **Did all students who received a passing grade demonstrate achievement of each course outcome? If not, why not and what actions do you recommend to remedy this problem in future offerings of this course? (Attach additional sheets as necessary)**

   Yes

   a. **How many course outcomes are there for this course? 5**
   b. **On a scale from 0 – 4 (0=not at all, 1=marginal, 2=adequate, 3=good, 4=very good), please rate, on average, the overall degree to which the students in this course achieved each of the course outcomes. (details on reverse side)**

Outcome 1	4	Outcome 5	4	Outcome 9		Outcome 13	
Outcome 2	4	Outcome 6		Outcome 10		Outcome 14	
Outcome 3	4	Outcome 7		Outcome 11		Outcome 15	
Outcome 4	4	Outcome 8		Outcome 12		Outcome 16	

2. **Are the course outcomes appropriate? If not, explain. (Attach additional sheets as necessary)**

   Yes – they are the standard "senior design" outcomes

3. **Are the students adequately prepared for this course and are the course prerequisites and corequisites appropriate? If not, explain. (Attach additional sheets as necessary)**

   Yes

4. **Do you have any suggestions for improving this course? If so, explain. (Attach additional sheets as necessary) Tweaks in lecture content (additional material on interfacing, embedded software development, new references for ethical and environmental lifecycle considerations), additional equipment for lab, larger quantities of standard supplies, purchase of a professional software package for maintenance of electronic lab notebooks – e.g. LabTrack (still looking for funds).**

Course Assessment Report, continued

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Average Outcome Scores and Outcome Demonstration Statistics for ECE 477 - 12/22/09

Outcome # 1 Avg Score:   85.3%    Passed:  38/ 38 = 100.00%    Failed:   0/ 38 =   0.00%

Outcome # 2 Avg Score:   82.9%    Passed:  37/ 38 =  97.37%    Failed:   1/ 38 =   2.63%

Outcome # 3 Avg Score:   93.7%    Passed:  38/ 38 = 100.00%    Failed:   0/ 38 =   0.00%

Outcome # 4 Avg Score:   85.8%    Passed:  38/ 38 = 100.00%    Failed:   0/ 38 =   0.00%

Outcome # 5 Avg Score:   87.6%    Passed:  38/ 38 = 100.00%    Failed:   0/ 38 =   0.00%

Demonstrated all five outcomes based on primary assessement:  37/ 38 =  97.37%
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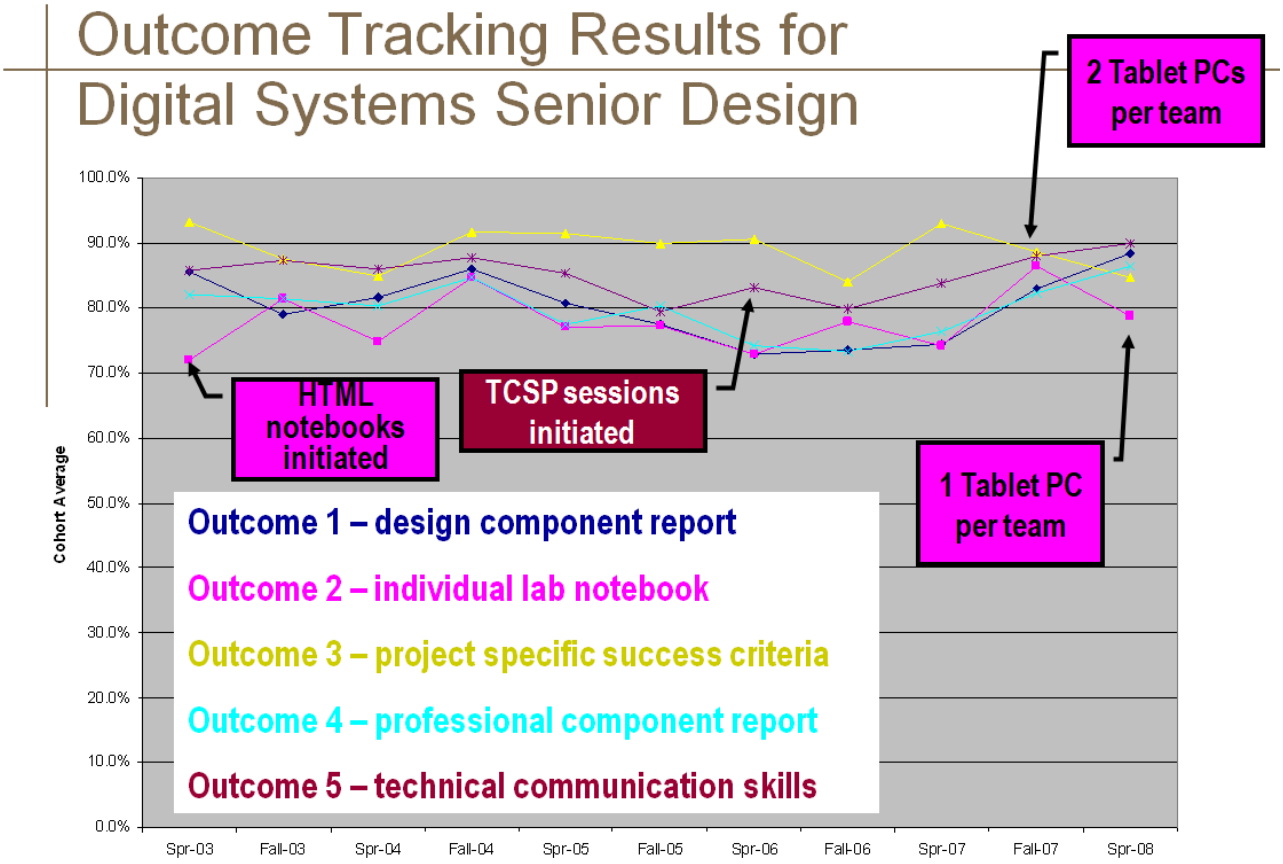
This table verifies that each student enrolled in ECE 477 Fall 2009 who received a passing grade demonstrated all the course outcomes. The chart below documents the tracking history of the average score for each outcome over multiple offerings.



Appendix A:

Senior Design Reports

Purdue ECE Senior Design Semester Report

Course Number and Title	ECE 477 *Digital Systems Senior Design Project*
Semester / Year	Fall 2009
Advisors	Prof. Meyer and Dr. Johnson
Team Number	1
Project Title	Gigaffect

Senior Design Students – Team Composition			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Arie Lyles	EE	PCB Design	May 2010
Brian Thomas	CompE	Software Design	May 2010
Henry Michl	EE	Packaging Design	May 2010
Joe Romine	EE	Hardware Assembly	Dec 2009

Project Description: Provide a brief (two or more page) technical description of the design project, as outlined below:

(a) Summary of the project, including customer, purpose, specifications, and a summary of the approach.

The Gigaffect is a live audio manipulator and loop station. It has the ability to add effects such as pitch, echo, and tremolo as well as the ability to capture loops from a live audio input. This device can simultaneously interface and process multiple microphone and instrument inputs. The intended customers for this device are musicians; this device allows them to enhance their music using the previously mentioned effects. These effects are realized through digital manipulation of audio using a microcontroller. (Audio will be digitized through an analog-to-digital converter before processing and un-digitized through a digital-to-analog converter post-processing.) The user interfaces with the Gigaffect through a series of pushbuttons and rotary encoders, which manipulate a menu and effect parameters on an LCD display.

(b) Description of how the project built upon the knowledge and skills acquired in earlier ECE coursework.

Most of the knowledge needed to complete this project came from two classes: ECE 270 (Introduction to Digital System Design) and ECE 362 (Microprocessor System Design and Interfacing). ECE 270 taught the basics of digital logic devices, and ECE 362 taught the basics of microprocessors. These lab-focused courses taught subjects such as microcontroller programming in assembly and interfacing with microprocessor peripherals. This project built upon the knowledge learned in ECE 362 due to the use of complicated microprocessors and interfaces that were constructed in this class. Parts used in this class

were not used previously, and their integration into a single working system provided a significant challenge.

(c) Description of what new technical knowledge and skills, if any, were acquired in doing the project.

During the course of this project it was necessary to learn how to use the PADS schematic and PCB design software. It had a very steep learning curve; nobody on this team had previously created a PCB. Furthermore, the majority of the devices integrated into this project were new to the members of this team; due to this, the team had to learn how these devices (such as rotary encoders and external memory) functioned. Additionally, due to the necessity of actually constructing hardware, the team's soldering skills greatly improved during the course of this project.

(d) Description of how the engineering design process was incorporated into the project. Reference must be made to the following fundamental steps of the design process: establishment of objectives and criteria, analysis, synthesis, construction, testing, and evaluation.

During the first few weeks of the class, the team defined its own PSSCs (Project Specific Success Criteria) which established clear objectives for our project. This gave the team a concrete problem that could be analyzed: the team wanted to create an audio manipulation device. To do this, they needed to find the necessary parts and materials, create block diagrams showing their integration, construct schematics, create PCBs, and develop packaging drawings. After receiving the packaging, parts, and PCBs ordered, project assembly began. This assembly was done in steps so that each step could be tested for functionality before moving to the next step. After the project was fully assembled and tested, the solution was evaluated in accordance to how well the PSSCs were satisfied.

(e) Summary of how realistic design constraints were incorporated into the project (consideration of <u>most</u> of the following is required: economic, environmental, ethical, health & safety, social, political, sustainability, and manufacturability constraints).

Economic: The Gigaffect, if manufactured, could provide new jobs to manufacturing companies. Additionally, this device may help musicians boost their careers through the use of new sounds and effects.

Environmental: The Gigaffect faces environmental challenges in manufacturing, use, and disposal. However, each of these challenges can be met and minimized through RoHS compliance, space-efficient design, power-reduction features, proper recycling techniques, and product life extension through firmware upgrades.

Ethical: The Gigaffect faces ethical challenges through issues in circuit design, risks from operating conditions, and hazards from user error. However, each of these challenges can be minimized or eliminated through the use of prerelease device testing, warning labels on

the device, documentation in the user manual, and added safety mechanisms on the device itself.

Health & Safety: The Gigaffect appears to be a rather safe and reliable product. With very few critical failures the product seems to have a relatively long life. Most of the components initially deemed prone to failure seem to have a very high MTTF (mean time to failure) which can only improve the life of the product. However, since the design of the Gigaffect was made without prior consideration for reliability, the Gigaffect is missing circuitry that could possibly protect or prevent some of the critical failures from happening. With the current current design, if one of the components fails, the product is considered useless. However, if safety circuits were put into the design, damage to the components could be reduced or even eliminated.

Social: The purpose of the Gigaffect is to facilitate the creation of music. As music is a method of social expression, the Gigaffect will help facilitate social expression.

Political: The only political consequences that could occur due to marketing of the Gigaffect relate to patents. The Gigaffect shares functionality with many patented inventions. There are plenty of inventions that create looping of or add effects to an input signal. Fortunately, these functions are very general and have substantial prior art associated with them. Given the large amount of prior art, and the fact that the Gigaffect does not use any other specific design, the Gigaffect should not infringe on any other patents.

Sustainability: Given the relatively low quantity of Gigaffect devices that need be manufactured (relative to PCs, cell phones, and the like which use the same resources that the Gigaffect uses), and given sustainable companies willing to manufacture the parts, it is possible for the Gigaffect to be a sustainable product.

Manufacturability: The Gigaffect is an extremely marketable product. The total cost of the Gigaffect prototype is well below the cost of similar products. The cost could be pushed even lower in mass production because the cost of parts would be lower when bought in mass quantities.

(f) Description of the multidisciplinary nature of the project.

It would be very difficult, if not impossible, to establish objectives, analyze, synthesize, construct, test, and evaluate a project like the Gigaffect without multidisciplinary cooperation. For the Gigaffect to function properly, hardware and software must be flawlessly integrated. Additionally, packaging also holds high importance in protecting both the user and the hardware from damage. To accomplish this, knowledge is required from different disciplines. For example, electrical engineers are needed to design, test, and debug the hardware. Computer engineers are needed to create and debug the software, and mechanical engineers are needed to create packaging that will be strong enough to withstand years of use.

(g) Description of project deliverables and their final status.

The Gigaffect has three main deliverables: the main unit, the footpedals, and the software. While we were able to accomplish all the objectives of our project, we were not able to accomplish them as fully as intended. At this time, the Gigaffect has the capability to digitize an analog input manipulate it via user input, and convert the manipulated digital signal back into an analog signal. The Gigaffect also has the capability to display information to the user on bar graph LEDs. Unfortunately, the LCD, rotary encoders, or footpedal pushbuttons were not integrated into our project due to hardware design flaws. The software is complete and runs perfectly on a standard Linux computer using ALSA and ncurses, with the additional option of libsndfile for recording audio. More effects could be added, and this would be trivial on top of the current software build. Integration with the Gigaffect hardware proved difficult due to the myriad of hardware flaws present on the board and the lack of development time after said problems were fixed. Given time, it is believed that all deliverables would be accomplished.

Purdue ECE Senior Design Semester Report

Course Number and Title	ECE 477 *Digital Systems Senior Design Project*
Semester / Year	Fall 2009
Advisors	Prof. Meyer and Dr. Johnson
Team Number	2
Project Title	The "Drink Mixer"

Senior Design Students – Team Composition			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
David Estes	EE	Software/Audio	December 2009
Levi Cowsert	EE	Hardware/Packaging	December 2009
Adam Johnson	EE	Software Development	December 2009
Susanne Schmidt	EE	Hardware Development	May 2010

Project Description: Provide a brief (two or more page) technical description of the design project, as outlined below:

(a) Summary of the project, including customer, purpose, specifications, and a summary of the approach.

The "Drink Mixer" is a digital audio mixer with individual input equalizer control as well as master output control. It is intended to fulfill the audio mixing needs of an aspiring DJ or band. The goal of this project is to create a great sounding board with low noise and effects processing capability. The prototype will have eight (mono) input channels, right and left main mix output, and two auxiliary mix outputs. Each channel will have its own set of equalization, gain, and pan controls, as well as independent fader control for the main and auxiliary mixes. It will also be capable of adding effects as well as saving and loading scene settings.

(b) Description of how the project built upon the knowledge and skills acquired in earlier ECE coursework.

In this project David contributed by providing a top down view of the project and past experience in audio processing. Courses like ECE 440 and ECE 438 provided experience with digital signal processing, while his own curiosity gave him the tools to experiment with embedded Linux well before the start of the design project. Levi contributed to hardware design and product packaging, as well as hardware debugging. His previous work in AutoCAD and CATIA V5 helped him greatly when designing the "Drink Mixer's" packaging. Adam's work in Purdue University's *Vertically Integrated Projects* program gave him experience with PCB design and embedded programming which assisted him as he was helping to design the project's user interface and develop the related firmware.

(c) Description of what new technical knowledge and skills, if any, were acquired in doing the project.

Because of the project's complexity, learning and practicing a top-down implementation strategy became very important to the "Drink Mixer's" design. Flowcharts and block diagrams helped tremendously in breaking the project into manageable parts, which could be prototyped and tested independently. Component selection is also a new skill for many of the design team members; navigating component selection tables on Digikey and Mouser will no longer be a challenge in future professional work.

Knowledge of PCB design was deepened this semester for all of the team members. Learning how to overcome pervasive software glitches in PADS layout and schematic software was key to circuit board design. Hardware debugging, soldering, and fly wiring were new skills for some team members, and learning to program a digital signal processor deepened team members' knowledge of audio mixer operation and technical requirements. Finally, learning about embedded Linux and inter-microcontroller communication protocols deepened our technical background.

(d) Description of how the engineering design process was incorporated into the project. Reference must be made to the following fundamental steps of the design process: establishment of objectives and criteria, analysis, synthesis, construction, testing, and evaluation.

This project, while performing a useful function, also stemmed from a desire to learn. The team chose a project that would be challenging. Performing mixing operations on audio required specific objectives to be set for the two main tasks the prototype would need to perform: interacting with the user and audio processing. From these objectives, project specific success criteria were created. When evaluating these criteria, it was decided that multiple processors should be used with communication between each other. This led to an analysis of what specific processes would need to happen simultaneously in the mixer. These included user interface controls for each channel, a display showing all relevant settings, and the audio mixing processes. It was decided that each channel would require its own processor, the audio mixing would require a digital signal processor, and another processor running embedded Linux would be used to oversee all of the other processors and run the display. Once this synthesis of ideas and solutions occurred, construction of the device began. Testing occurred throughout the construction process to verify that separate components and sections worked individually before adding them together as a whole.

(e) Summary of how realistic design constraints were incorporated into the project (consideration of <u>most</u> of the following is required: economic, environmental, ethical, health & safety, social, political, sustainability, and manufacturability constraints).

Economic: It was desirable to keep the cost for the "Drink Mixer" as low as possible. Several of the microcontrollers were chosen because they were readily available and did not need to be purchased.

Environmental: The first prototype of this device contains leaded solder and mercury in the touch screen. This can be hazardous to the environment if not disposed of properly, but disposal instructions are contained in the user manual. The casing is made of aluminum, so it can easily be recycled. As long as the user disposes of the device properly, there are no environmental concerns.

Ethical: The Drink Mixer was made as safe as possible, using components that were known to be safe and reliable. During testing there was one component found to be significantly more unreliable than most, that component being the h-bridge. This component will be replaced and its interface redesigned in future prototypes and production models to ensure safety and ethical integrity.

Health & Safety: Each of the different microprocessors contained within the product were critically analyzed, and their mean time to failure was calculated. It was also determined that the weakest link in the processors is the ADSP-21262 SHARC Processor, with the highest failure rate. The schematic has been broken up into several different functional blocks, and each of these blocks analyzed for critical failures. Each of these critical failures was then looked at and a probable cause determined, along with its severity and consequences. It has also been determined that there are incredibly few possibilities of an error or malfunction that could cause harm to the user or bystanders. As a result of this, almost any error that would occur is simply a nuisance or functionality error.

Social: As this device will be used in a social setting, the packaging was created to be attractive and as compact as possible.

Political: The "Drink Mixer" is free of patent infringement both literally and under the doctrine of equivalents. The concept of mixing audio is rather old and can no longer be patented. Several patents were looked into including patents on the ornamental design, also known as packaging and control layout, as well as audio mixing systems. There is no threat for infringement due to our control layout. Also, patents that describe audio mixing systems reference prior art for the same functions that the "Drink Mixer" is capable of.

Sustainability: The packaging of the device was created with a long life in mind. It should be able to endure a fair amount of physical abuse. Upgradeability was also taken into consideration in the design stages. The USB drives used for programming are also there in hopes of future wireless or Ethernet capabilities.

Manufacturability: Careful consideration was taken to ensure that all of the PCBs were of a size that would fit appropriately in the packaging, alongside other components that weren't on the PCBs. Many harnesses were necessary to connect the PCBs and other components to each other as well as to the terminal blocks, which provided power.

(f) Description of the multidisciplinary nature of the project.

Creating a digital audio mixer required many skills not covered in the realm of Electrical Engineering. The hardware and software for the project were within the scope of Electrical Engineering, but the packaging required branching out more towards Mechanical Engineering. Outside of engineering, challenges faced included technical writing for the reports that were due once a week, as well as financial responsibility when choosing the most cost effective parts.

(g) Description of project deliverables and their final status.

The "Drink Mixer" is safely packaged and all of the hardware has been completed, but the final programming is incomplete. The analog to digital converters are currently not communicating properly with the DSP, and as such the audio portion is not currently functional. Even though audio is non-functional, three of the five project specific success criteria were accomplished. The two that were not accomplished were: 1. An ability to digitally mix audio and adjust individual levels; and 2. An ability to display amplitude of output signal. It is not possible to display the amplitude of an output signal without first having the signal pass through the system.

The "Drink Mixer" is currently capable of the following: 1. An ability to adjust individual equalizer settings for the input channel; 2. An ability to display channel settings on an LCD display; and 3. An ability to save and load scene settings. There are RPG's on each channel to adjust the gain of the input as well as change settings on the LCD display. There are buttons to turn channels on or off, lighting up green or red respectively. The LCD display is used to save and load settings, as well as give detailed information about gain and equalizer settings for each channel. Along with loading the saved scene settings information onto the LCD display, buttons will light up appropriately and the motorized faders will move to the saved locations.

Purdue ECE Senior Design Semester Report

Course Number and Title	ECE 477 *Digital Systems Senior Design Project*
Semester / Year	Fall 2009
Advisors	Prof. Meyer and Dr. Johnson
Team Number	3
Project Title	Wireless Surround Sound System (WS3)

Senior Design Students – Team Composition			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Brendon Caulkins	CmpE	Packaging, Hardware	Dec 2009
Kunal Kapoor	CmpE	Software	Dec 2009
Anderson Nascimento	CmpE	Schematic, Software	Dec 2009
Ben Rafferty	CmpE	Hardware, PCB	Dec 2009

Project Description: Provide a brief (two or more page) technical description of the design project, as outlined below:

(a) Summary of the project, including customer, purpose, specifications, and a summary of the approach.

The WS3 is a wireless surround sound home theater system. It is intended to be portable, easy to set up and require minimal technical knowledge to use, making it an ideal product for everyone that wants surround sound on the go. The system consists of five components: a base and four satellite speakers. The base houses the audio inputs, center speaker, subwoofer and wireless transmitters. Each satellite speaker box houses a wireless receiver, battery (and charger), and a speaker.

The intended customer is basically anyone who wants a surround sound system. More specific customers would include anyone who wants their system to be mobile, allowing for easy take-down and setup, or anyone who does not want to run wires around the room in order to set up a surround sound environment.

Our approach was to simplify the wireless communication and focus on ease of use and user friendliness. To that end, we opted to use the DARR-80 wireless audio module to handle all of the wireless communication. On the transmitter, the analog to digital converters output directly to this module, and on the receiver the digital to analog converters receive data directly from this module. Connection is established as soon as both the base and a satellite speaker are turned on. Other speakers connect as soon as they are powered on, without requiring any further action. Satellite speakers seamlessly

switch from battery to AC power. User interface is simple that quickly adjusts basic settings like volume, balance, and fade.

(b) Description of how the project built upon the knowledge and skills acquired in earlier ECE coursework.

Many principles from previous ECE coursework were used to build our project. We used concepts and skills from ECE270 such as fan-out, current/voltage requirements and limits, and even simply reading datasheet were essential when designing our circuits with different chips that interfaced to each other. Even more crucial was the use of ECE362 knowledge. We had to set up timers, service interrupts, and debounce buttons in software, all of which we learned in ECE362. Also extremely useful was the basic knowledge of ECE201 concepts. V=IR is always good to keep in mind.

(c) Description of what new technical knowledge and skills, if any, were acquired in doing the project.

There were certainly some new technical knowledge and skills acquired in the process of doing our project. One of the first things was learning about analog to digital and digital to analog converter chips and their typical interfaces. We needed converters that output I2S, and therefore needed to learn a bit about I2S. More importantly, we had to learn how to configure different converter chips as master and slave, and which one must drive what lines on the bus at what time. Another big thing we had to learn was how to use Mentor Graphics PADS for schematic, PCB layout, and PCB routing. Learning how to create parts was the easy part, but the more complicated things were placing the parts on the pcb, arranging them to separate analog, noisy/digital and power sections, and then routing all the connections in a sane manner. Software was also slightly new to us. We used a version of gcc for embedded systems called avr-gcc. We learned how to access registers, use built in libraries, set up interrupt service routines, and perhaps the best thing we learned was how to shrink the size of the binary program by 60% simply by linking the right precompiled libraries.

(d) Description of how the engineering design process was incorporated into the project. Reference must be made to the following fundamental steps of the design process: establishment of objectives and criteria, analysis, synthesis, construction, testing, and evaluation.

Our first major task towards completing the project was defining a clear set of project specific success criteria. These criteria should define attainable goals that demonstrate that our project is successful. After our initial goals were defined, we began researching and selecting parts for use in the project. We created a preliminary block diagram, and began working on our detailed schematic while at the same time creating prototype circuits with sampled parts. After finishing our initial schematic, we began working on our PCB layouts. Because we were working with limited knowledge of the detailed workings of the wireless modules, a significant working of the schematic and a complete redesign of

the PCB layouts was necessary. After finalizing our PCB designs and receiving the manufactured boards, we began the population and testing process. We populated each board incrementally, beginning with the power supply, and testing each portion of the circuit individually. There were a few small issues with our circuit boards that required modification, but for the most part, our designs were successful. After populating the boards and testing the hardware, the software and debugging process began. The software for our project was fairly simple, and mainly consisted of interfacing with the various components in our circuit. There were no significant computation tasks that needed to be performed by the microcontrollers themselves. The most difficult part of the software to write and debug was the initialization and configuration process for the wireless modules. Once we were able to get the modules connected and transmitting audio, we were nearing completion. After this point, our biggest concerns were finishing user interface and packaging details.

(e) Summary of how realistic design constraints were incorporated into the project (consideration of most of the following is required: economic, environmental, ethical, health & safety, social, political, sustainability, and manufacturability constraints).

Economic: It was our hope that our system would be comparable in price, or cheaper than other similar products that are currently in the market. To that end we chose parts that were readily available (with the exception of the DARR-80) and when given the option between two compatible parts, we normally picked the cheaper one.

Environmental: There are no significant environmental constraints to be concerned with for our project. Lithium-ion batteries are not classified as hazardous, and can be disposed of in an environmentally friendly way. Our prototype PCB uses leaded solder, but a final production version can be made entirely lead free and RoHS compliant.

Ethical: We wanted the battery to last as long as possible, so a constraint was that our batteries would be charged properly as to not damage it more than usual over time. This would prevent the user from having to replace the product within a short period of time. We tried to accomplish this by using a battery charger chip that had already been adequately tested to charge our battery.

Health & Safety: The battery was also a safety hazard. We also did not want the battery to explode or leak harmful chemicals. This is normally taken care of by correct use (charge/discharge) of the battery. It was therefore once more important to use a battery charger chip that could handle all of this for us. Another possible health issue would be the audio levels damaging people's ears. This was intrinsically taken care of by our low power/high efficiency audio amplifiers, which will not output more than 2W per channel.

Social: One of our top priorities for this project was to make it as portable as possible. It was our hope that it could be taken on short trips, used in hotels without disturbing neighboring rooms, and be as simple to set up as possible. We believe we have mostly achieved this. While the base module is slightly larger than we originally envisioned it, it

can still fit inside of a duffle bag. On the other hand, the satellite speakers make up for the size of the base module. They are very small, and compare to small computer speakers. The whole system fits inside of a small duffle bag.

Political: Our only political concern is wireless laws and regulations. The DARR80 module uses the worldwide license free 2.4 GHz range, which means we do not need to be concerned with this issue.

Manufacturability: Our project would not have any serious manufacturability concerns if it were to be brought to production. Speakers similar to the ones we used are already being mass produced by a wide range of companies. The only significant difference would be the addition of the PCBs, wireless module, and lithium ion battery to the inside of the satellite speaker case.

(f) Description of the multidisciplinary nature of the project.

Our project lent itself to a couple of different disciplines. Electrical Engineering knowledge and skills were used to design not only the digital but also the few analog components of our circuits. Computer Engineering knowledge and skills were used in designing the digital interfaces between different chips, and in programming the microcontrollers. Although by now we have gotten used to writing technical papers and giving technical presentations, a communications major would have been great help both in giving better presentations and writing better reports, especially the user manual, which should be much less technical. In the process of better illustrating the physical design of our project, we also drew up CAD drawings, which required a background in CAD Design. Should we have decided to make our own enclosures instead of reusing an old surround system, we would also required skills in machining tools.

(g) Description of project deliverables and their final status.

Our intention was to ultimately have a full surround sound system implemented. That means that the project deliverables are: one base module, four satellite speakers, and power connectors for all five.

However, to accomplish all of our PSSC's, we only needed to implement the base module and one satellite speaker. Also, because STS only donated 4 DARR-80 modules, we would only ever been able to make 3 satellite speakers plus the base module. Because of these and other factors, we only made one base station and one satellite speaker.

The base station works as intended, being able to transmit 4 channels of audio and set the volume for all channels. It also displays balance and fade levels on the LCD, but adjusting either will not actually change the settings, as these were not fully implemented. Battery levels also do not display correctly on the LCD because the battery level messages were also not fully implemented.

The satellite speaker works exactly as intended, being able to receive any of 4 different audio channels. It can also accept volume messages from the base module and adjust its volume accordingly. It monitors the battery status and displays an approximate charge capacity on an LED bar fuel gauge. It can charge the battery if an AC adapter is plugged in, and will seamlessly switch from AC to battery and back when AC adapter is removed or inserted. The only thing that the satellite speaker does not do is respond to requests for battery levels simply because we did not have time to implement that.

It should be noted that we populated and otherwise connected the required PCBs for another satellite speaker, but we did not get around to putting these guts inside of a speaker case. It did, however work the same as the finished speaker.

Purdue ECE Senior Design Semester Report

Course Number and Title	ECE 477 *Digital Systems Senior Design Project*
Semester / Year	Fall 2009
Advisors	Prof. Meyer and Dr. Johnson
Team Number	4
Project Title	Purdue Interactive Kiosk (PIKO)

Senior Design Students – Team Composition			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Zachary Curosh	CmpE	Software/Reports	May 2010
Travis Safford	CmpE	Soldering/Packaging	May 2010
Matt Swanson	CmpE	Software/GUI	May 2010
Jevin Sweval	CmpE	PCB/Low-level Software	May 2010

Project Description: Provide a brief (two or more page) technical description of the design project, as outlined below:

(a) Summary of the project, including customer, purpose, specifications, and a summary of the approach.

The Purdue Interactive Kiosk (PIKO) is a web-enabled, touch screen information portal designed for use by Purdue students, faculty, and campus visitors. The purpose of PIKO is to eliminate short trips to computer labs by students and staff and to allow visitors to navigate and learn about Purdue's campus more easily. PIKO is designed to be placed in a location of high campus traffic where the most users will be able to take advantage of its various applications. These Purdue-oriented applications include a way for students and faculty to quickly check their e-mail, a Purdue directory system, a list of available computer labs on campus, a schedule and results of the Purdue football team, a campus map, and a list of campus-relevant news stories. A touch screen is used to select an application and navigate the graphical user interface (GUI). The GUI is designed to be user-friendly and visually appealing.

PIKO also comes complete with several peripherals to enhance its functionality. A PS/2 keyboard allows users to input their passwords and search the electronic directory, while a magnetic card reader allows users to swipe their Purdue ID cards so their usernames can be automatically entered when using the e-mail application. A passive infrared (PIR) occupancy sensor allows the kiosk to sense when it is being used; when it is not in use, the LCD display and Atom board "go to sleep" so the kiosk reduces its power consumption. The touch screen allows users to quickly and easily make choices when using PIKO. All of these peripherals are implemented using a custom support board PCB. This board has headers for these peripherals to be connected to, and the board outputs a single USB

connector to the Atom board which allows the peripherals to communicate with the application software. These peripherals are able to communicate using a single USB connector since PIKO implements a composite USB device in which all of the peripherals' signals are sent over a single USB connector.

The body of the kiosk has a sleek, metal design which will be appealing to the user. The monitor and touch screen are housed inside a plywood frame so that the user may easily see and access the touch screen. The keyboard is placed below the LCD screen at arm level for ease of use. The card reader is housed at arm level on the right side of the kiosk so that it may be easily accessed by the user, while the occupancy sensor is placed below the keyboard tray so it can easily determine if the kiosk is in use.

(b) Description of how the project built upon the knowledge and skills acquired in earlier ECE coursework.

This project allowed us to apply the knowledge and skills that we have learned from previous ECE courses. The most critical of these was the use of our acquired software knowledge. Classes that taught the C programming language, such as ECE 264, were crucial as the coding done on the microcontroller was done using C. The application software was written in Python, which was introduced in ECE 364. Knowledge about interface design, object-oriented programming, and threading that was gained from ECE 462 was crucial in developing the kiosk application software. Another important course was ECE 362, as it taught us how to understand, use, and program a microcontroller. This course not only taught how to use the various peripherals that were incorporated with the microcontroller, such as SPI and the ADC converter, it also taught how to understand and use the documentation of a microcontroller. This skill was critical as we had to choose a microcontroller to be used, so we needed to learn about the various features each one contained in order to make the right choice quickly. The final coding of the microcontroller contained interrupt and flag driven coding, and ECE 362 taught the different coding styles that could be used in a microcontroller. Some analog skills and knowledge were also necessary when designing the PCB, such as knowledge of capacitors and power circuitry. These hardware skills were acquired from working in the labs for ECE 207 and 208, as well as ECE 255.

(c) Description of what new technical knowledge and skills, if any, were acquired in doing the project.

Since all members of Team PIKO are Computer Engineers, we did not have extensive knowledge of analog circuitry, specifically PCB design. We had to learn how to use PADS, as well as learning where all parts are to be soldered and why the parts go there. We also had to research appropriate sizes of trace widths and how to use ground and copper pours. Once the board was fabricated, few team members had experience in soldering, so learning how to solder properly was critical. While most of the team had done small software projects, the kiosk application was a larger scale project and the team had to learn the skills to develop a piece of software from the ground up. One of the most crucial

parts of the kiosk was the ability to connect several peripherals to the Atom board through one USB cable. The team gained knowledge about how to use and integrate the available USB LUFA libraries found online, which was used to create a composite USB Human Interface Device (HID). The kiosk first interfaces with the peripherals' native connections, such as PS/2 for the keyboard, and then combines the peripherals into a single composite USB device. The team had to spend a considerable amount of time learning about USB protocol and about the LUFA libraries. Finally, the team gained experience working in a long-term project group.

(d) Description of how the engineering design process was incorporated into the project. Reference must be made to the following fundamental steps of the design process: establishment of objectives and criteria, analysis, synthesis, construction, testing, and evaluation.

The first step in designing PIKO was to actually decide on what the project would entail. The team came to decide that it would design a touch screen information kiosk with certain features. These features came to be the objectives of our project. Once we decided on our objectives, we planned out a rough schedule for when we wanted to accomplish our goals. The next step was to decide what components would be needed to make the kiosk run with the desired performance. We had to analyze each component individually to decide which one would perform the best for the most appropriate cost. The team also had to analyze the components that would be selected for use in the PCB. Once the PCB arrived, we began to test our software on the PCB and Atom board to ensure that our code worked as expected. The code was split into two main parts: the end-user application written in Python and the microcontroller software written in embedded C. Once each part was sufficiently tested and debugged, we were able to combine both code segments to run at the same time. During this time, the team also worked on the packaging for the kiosk. The body of the kiosk, donated by Chuck Barnett, is made out of metal, so the team then had to figure out how to integrate the LCD and peripherals into the body of the kiosk. We were able to design the appropriate mounting hardware and successfully retrofit the body with our project components. Once the kiosk was packaged, we once again tested the functionality to verify that everything works as expected. Final evaluation of the success of the project was determined by demonstrating the working project to course staff and peers.

(e) Summary of how realistic design constraints were incorporated into the project (consideration of <u>most</u> of the following is required: economic, environmental, ethical, health & safety, social, political, sustainability, and manufacturability constraints).

Economic: The main economic impact of PIKO is that it has to be less expensive than information kiosks sold commercially. These kiosks were in the range of around $1500 for just the stand, not including hardware and software development costs. Our kiosk cost between $500 and $600 to produce. We also wanted to provide a quicker alternative to getting the kiosk content than from a short trip to a computer lab, but if the kiosk proved to be more expensive than a computer, it may not be a viable option to replace these short

trips to labs. So depending on the cost of a computer unit, this may or may not be economically feasible; the customer will have to decided between a trade-off in speed and convenience versus cost.

Environmental: Outside of the risk of electronic devices containing lead and mercury, PIKO will have minimal environmental impact. The one consideration the team took into account was that the kiosk was designed to be always on, so the kiosk could potentially use a lot of power. This problem was resolved by using an occupancy sensor to detect if there is a user near the kiosk. If there is no user, LCD screen and Atom board will go to sleep and the kiosk enters "low power mode" which will reduce the environmental impact of the product.

Ethical: The main ethical concern Team PIKO took into account was software integrity. Special consideration was taken to make it difficult for users to access anything other than the kiosk application. While it is not impossible for malicious users to install malware or key loggers, we made our best effort to protect against this. The information displayed by the kiosk comes primarily from Purdue-hosted content, which should help to ensure that there is nothing explicit or unethical being displayed.

Health & Safety: There are few health or safety concerns with PIKO. The kiosk is quite heavy, so it could severely injure someone if it were to fall. Warning labels are provided as well as instruction to the owner telling them to be sure to stabilize the kiosk. The touch screen is quite durable, but if a user were to hit it hard enough, the glass could shatter and potentially injure the user, so warning labels will once again be provided. Since this is a touch screen kiosk, the touch screen could potentially be unsanitary from public use. The documentation with PIKO suggests that the owner clean the screen regularly, as well as provide hand sanitizer for PIKO users.

Social: PIKO could potentially have a large social impact. It is designed to be placed in high traffic areas on Purdue's campus so the maximum amount of users pass by. It will help people get around Purdue's campus as well as find out relevant Purdue information very quickly.

Sustainability: PIKO is designed to be extremely sustainable. The life of the product will be determined by how long the software and firmware are up-to-date, but Team PIKO will lengthen the life of the product by offering both software and firmware updates when available. The kiosk has all boards and wires mounted in the back panel of the stand, so users will have to actually open up the packaging (which is locked) to even make any attempt to damage the product. This packaging scheme also protects the PCB and single board PC from environmental or other accidental damage that might happen in a public setting (spills, dirt, etc).

Manufacturability: As an information kiosk, PIKO is very competitive price-wise, so in this way it makes the kiosk extremely marketable. However, to offer a viable alternative to short trips to a computer lab, PIKO must offer competitive pricing with a lab computer in

order for the kiosk to be an effective solution. The project was designed for modular use. The software can be ported to another single-board platform if desired (this was actually done during the course of the project due to damage to our original single-board PC) and the support board converts the peripherals into a composite, USB device which can be easily integrated with alternative hardware.

(f) Description of the multidisciplinary nature of the project.

This project required skills from both electrical and computer engineering. The circuit and PCB design relied heavily on knowledge obtained in electrical engineering courses, such as ECE 201, 202, 207, 208, and 255. PIKO is a software intensive project so most of the skills required came from the computer engineering. ECE 362 taught us about microcontroller design and programming. ECE 364 and 264 taught about Python and C respectively which were crucial in the design of PIKO. Since there are both hardware and software components, as well as analog and digital components, of the project, being well-versed in both electrical and computer engineering was of immense help.

(g) Description of project deliverables and their final status.

PIKO was completed on time and completely functional. We were able to complete the packaging of the kiosk, and all of the PSSCs functioned completely after packaging. The kiosk successfully ran the end-user software: the card reader correctly identified users, the occupancy sensor determined if there were users near the kiosk, the keyboard allowed users to input their passwords or search the directory, and the touch screen allowed users to navigate and make selections on the kiosk application. The peripherals communicate successfully with the Atom board over a USB connection. PIKO was packaged in a metal kiosk base with the external peripherals being packaged in their own plastic enclosures. The LCD and touch screen were mounted on the kiosk and surrounded by black plywood frame to protect them and to be more visually appealing.

Purdue ECE Senior Design Semester Report

Course Number and Title	ECE 477 *Digital Systems Senior Design Project*
Semester / Year	Fall 2009
Advisors	Prof. Meyer and Dr. Johnson
Team Number	5
Project Title	Blinkers++

Senior Design Students – Team Composition			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Ian Oliver	EE	PCB and LED output configuration	May 2010
Jacqui Dickerson	EE	Packaging	May 2010
Ben Carter	EE	Microcontroller interfacing and development	December 2009
Dennis Lee	EE	Multi-touch algorithm and touchpad controllers	December 2009

Project Description: Provide a brief (two or more page) technical description of the design project, as outlined below:

(a) Summary of the project, including customer, purpose, specifications, and a summary of the approach.

Blinkers++ is an inter-car communication system that provides a more dynamic and intuitive method of communication. The user will interact with the device using a capacitive touch array that will be able to accept and interpret multiple finger touches. The output for the device will be displayed on LEDs placed around the car's perimeter. Specific LEDs will illuminate a certain color based on the interpreted gesture. For example, one finger swipe to the rear would indicate gratitude for letting the driver enter traffic. The corresponding LED pattern would be a smooth pulse of blue light on the rear LEDs. Another example would be a two finger swipe to the left bottom to indicate to other drivers the intent to parallel park. The corresponding LED pattern for this gesture would be two green pulses to the driver's rear side of the car indicating a "clear to pass" message. Finally, in the event of a sudden stop, Blinkers++ will use its LED array to alert surrounding drivers with a three quick pulses of red and orange light.

(b) Description of how the project built upon the knowledge and skills acquired in earlier ECE coursework.

This project utilized many skills gained from our electrical and computer engineering curriculum. Classes that emphasized software, such as C programming or object oriented design, taught us sound software design and allowed us to effectively program our microcontrollers. These skills were especially useful when designing an algorithm to read multi-touch inputs and determine the direction of finger swipes. Microprocessor Systems and Interfacing, a class which was a prerequisite for senior design, acquainted us with the basic peripherals needed to make any microcontroller function. For example, the I2C peripheral was vital for communication between the touchpad controllers, dsPIC, and LED controllers, and UART enabled wireless communication. More hardware oriented coursework such as electronics labs (ECE 207 and 208) taught us analog skills helpful for PCB design.

(c) Description of what new technical knowledge and skills, if any, were acquired in doing the project.

We learned sound PCB layout principles through the design of our multi-touch pad and satellite LED boards. In particular, our multi-touch pad required care in the location and placement of traces and vias. The user touchpad side of the PCB used square copper traces which acted as capacitive-sensing buttons, and this area did not have any traces so that the touchpad controllers could properly sense fingers. Vias had to be placed in the middle of each button and routed to touchpad controllers underneath the board. The touchpad controllers were located close to the buttons so that traces were not too long, in order to minimize noise when reading button inputs. In addition to optimizing trace placement, we learned about the importance and sizing of decoupling and bulk capacitors and improved our soldering skills with these small components.

(d) Description of how the engineering design process was incorporated into the project.

Our project stemmed from the current lack of effective communication among drivers on the road. To remedy this problem, we envisioned making a multi-touch pad that would control output on LEDs placed around a car. Once we had a general idea of what we wanted to do, we listed design criteria that would guide our project. The multi-touch pad had to be intuitive to use and small enough to place on the steering wheel of a car. With these criteria, we established some clear objectives for our project to be successful. These objectives included the abilities to determine the number and direction of fingers on the touchpad, to produce at least two meaningful LED patterns around the perimeter of a car, to determine the force of acceleration on a car, and to transmit data wirelessly from the touchpad to the LED controller on the car. Then the team analyzed how these objectives could be fulfilled with a sound digital design. The design included multiple touchpad controllers for reading clusters of capacitive touch buttons, a digital signal processor for analyzing the touchpad inputs, and a microprocessor to control the LED patterns around a car. During the synthesis phase, the PCB was designed and pseudo-code for our

microcontrollers was written. Next our board had to be constructed by soldering all our discrete components on our PCB and modifying a model car to display LED patterns. After construction each component of the board had to be tested, including the power supply, touchpad input reading, and microcontroller functionality. Once testing and debugging were complete, the team evaluated whether all the objectives were met. In the end, our project achieved all the goals, and it could successfully interpret a multi-touch gesture and output a corresponding LED pattern.

(e) Summary of how realistic design constraints were incorporated into the project

Economic: Our project was originally dictated by cost since we couldn't acquire a multi-touch pad for development from anywhere for under $1000. With this design constraint, we proceeded to look into constructing our own. The team determined that the cheapest and most effective way for us to build a functional multi-touch pad would be with an array of capacitive touch buttons. We received a generous donation of capacitive touch controllers that reduced our development cost. Since the estimated cost for the prototype not including the RC car was approximately $300, we feel that this would be a reasonable add-on to current vehicles.

Environmental: Because Blinkers++ piggybacks on existing power infrastructure (i.e. that of automobiles) and uses RoHS-compliant components, its capacity for harm to the environment is minimal. In manufacturing, sustainable processes and lead-free solder will limit impact to the environment. During the functional life of the product, Blinkers++ is of little consequence to the environment, as power is taken from an existing power source, no replacement of parts is anticipated, and no heavy metals or exotic and dangerous substances are used anywhere in the project. At the end of product life, Blinkers++ will be interred in the same manner as the vehicle in which it is integrated. Because of the highly integrated nature of Blinkers++, it is not generally possible to remove the system "a la carte". Thus, Blinkers++ has an extremely limited ability to negatively impact the environment over the product life cycle.

Ethical: Because Blinkers++ is a system meant to be used in the high-speed, high-risk environment of America's highways, a unique set of ethical concerns are worthy of examination. For example, some may be concerned that Blinkers++ may distract the user from his duties as a driver. The team is confident that the gesture-input system is simple enough to be used without looking directly at it, though the radios and CD players currently commonplace in vehicle cabins cannot say the same. This greatly reduces the risk of using the device. Because of the potential for dangerous situations to result in the case of erroneous output, the Blinkers++ team has labored to make these occasions few and far in between.

Health & Safety: Our project does not involve extremely dangerous parts, such as motors or guitar strings. The touchpad is designed to be intuitive to use and should not pose too much of a distraction for the driver. If the output patterns happen to be incorrect, then the user has the option of turning off the touchpad.

Social: Blinkers++ could change the way the world looks at driving and road rage. Society is free to change the meaning of each LED pattern as the world changes, similar to how the meanings of words have changed over the years. The Blinkers++ team hopes that the introduction of Blinkers++ will curb road rage and create more pleasant roadways.

Political: The political aspects of Blinkers++ could be large scale. Laws may need to be changed to encourage the use of signaling using Blinkers++ in tandem with already established turn signals. However, there may be some opposition due to the costs of installing our project in a car.

Sustainability: Parts of our design are sustainable, but other parts may not be as sustainable for a production setting. For example, our power supplies can be easily replaced, since they draw on the car's battery. However, the PCB may not be as easily replaced. In future iterations, a more robust design might separate the touchpad and microcontrollers, so that the touchpad can be easily replaced if broken. The current design is only a prototype, so functionality was emphasized more than sustainability.

Manufacturability: The team decided that the best way to prototype the Blinkers++ system was with an RC car. This required considerable thought in PCB trace routing and LED placement within the car. In order to maximize clarity in construction and minimization of loose cables, the team elected to manufacture 14 individual PCBs each with a driver chip and 5 LEDs. Using this strategy, the team was able to evenly mount the PCBs inside the car and daisy-chain the whole group together using easy-to-route cables. The market version of the Blinkers++ device is to be installed on the production line of the vehicle. That is, the LEDs should be placed in the car's side panels and the power supplies should be attached to the car battery as it is manufactured.

(f) Description of the multidisciplinary nature of the project.

Blinkers++ relied on more than just computer engineering to complete the task. We used our electrical engineering knowledge to create schematics and design PCBs. Our knowledge of electrical engineering proved useful even later in the semester as we reduced the noise on our communication busses by exchanging resistive components on our board. For a long period of time however, the team benefited greatly from our digital design skills. Sound software design allowed us to accomplish everything from low level system operations through multi-touch data processing and noise filtering. In addition, the team needed to employ knowledge of marketing techniques since our design claims a user-friendly interface.

(g) Description of project deliverables and their final status.

There are two main deliverables for Blinkers++. There is a user interface box which consists of a PCB multi-touch pad with 20 LEDs. The multi-touch pad will take the user's input and display user feedback on the 20 LEDs on the perimeter of the box. This user module had full functionality including displaying different LED light patterns. The other

deliverable is a remote controlled Escalade which consisted of a PIC18 board and 14 LED driver boards, each with 5 LEDs. The PIC18 board was zip-tied to the roof of the car and cables were constructed to connect all LED driver boards to the PIC18 board. The 14 LED driver boards were situated around the inside perimeter of the vehicle, and their corresponding LEDs were fitted through holes in the shell of the Escalade.

Purdue ECE Senior Design Semester Report

Course Number and Title	ECE 477 *Digital Systems Senior Design Project*
Semester / Year	Fall 2009
Advisors	Prof. Meyer and Dr. Johnson
Team Number	6
Project Title	Self Tuning Guitar

Senior Design Students – Team Composition			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Matthew Barton	EE	Packaging, hardware, guitar specialist	Fall 2009
Patrick Nice	ECE	Microcontroller code, circuit design	Spring 2010
Cliff Risley	EE	PCB designer, Testing and debugging specialist	Fall 2009
Seth George	ECE	Computer software designer	Fall 2009

Project Description: Provide a brief (two or more page) technical description of the design project, as outlined below:

(a) Summary of the project, including customer, purpose, specifications, and a summary of the approach.

The self tuning guitar is a revolutionary system designed to provide musicians with a low cost way to tune their guitar, quickly and easily. An onboard user interface provides the musician with the ability to select different tunings, string up the guitar and tune one or more strings simultaneously. In addition the self tuning guitar is equipped with Bluetooth capability which allows a stage hand to monitor the status of the guitar and change the guitar's operating parameters from back stage using custom built software. The self tuning functionality of the system is achieved in three steps. First an audio codec samples the guitar's pickups and amplifies the signal to a usable level. Next the audio data is transmitted to a DSP (digital signal processor) which performs a Fourier transform on the captured sample and analyses the output to calculate the frequencies of the strummed strings. Finally, the DSP converts the calculated frequencies to PWM signals which turn the continuous rotation servos attached to the tuning machines of the guitar.

(b) Description of how the project built upon the knowledge and skills acquired in earlier ECE course work.

This project was made possible by skills that were acquired in previous ECE courses. Two absolutely indispensable courses were Introduction to Digital Systems (ECE 270) and Microprocessor System Design and Interfacing (ECE 362). These classes provided a foundation in digital system operation, valuable embedded system design experience and exposure to the most popular microcontroller peripherals and interfacing methods. Lessons learned in Intro to Signal Processing (ECE 301), were applied through the use of FFTs (fast Fourier transform) to analyze the input from the guitar. Electromechanical Motion Devices (ECE 321) provided knowledge of the different types of electric motors and aided the team in selecting the motors that would be used to turn the guitar's tuning machines. The courses on Linear Circuit Analysis (ECE 201 & ECE 202) were used in designing basic circuit modules like power supplies and voltage dividers. Finally Advanced C Programming (ECE 264) armed the team with the ability to write the embedded microcontroller and the PC application software.

(c) Description of what new technical knowledge and skills, if any, were acquired in doing the project.

The study of the frequency of guitar strings and evaluating them to determine an algorithm to successfully tune each string based the output of the FFT was studied extensively. Also, much research was done to properly construct the printed circuit board. Designing a circuit board that meets the specifications of a demanding audio codec was a huge part of the design process. Also, a very extensive study was done on power supplies and determining how to handle cases that involves vastly different power requirements and how to fulfill those requirements utilizing batteries and regulators.

(d) Description of how the engineering design process was incorporated into the project. Reference must be made to the following fundamental steps of the design process: establishment of objectives and criteria, analysis, synthesis, construction, testing, and evaluation.

The idea for the Self-Tuning Guitar was conceived in the spring of 2009 when the group was formed. The objectives of the project were decided upon while thinking about what features a musician would find useful in a self tuning guitar. The system would have to be lightweight, portable and unobtrusive to the player. Regarding functionality, the team developed a list of technical requirements. These requirements then became our project specific success criteria. With the goals of the project in hand the team began analyzing the physical system to which we would have to eventually mate our project: a guitar. The first step was to capture the output of an electric guitar, perform FFT's on captured data sets and begin to sort out ways that the data could be converted into the frequencies of each string. From the initial tests on the guitar enough data was collected to allow a DSP capable of meeting our computation requirements to be chosen. It also took a lot of analysis to determine the requirements for the tuning motors. The torque required to turn the tuning

pegs was calculated used to find motors strong enough and precise enough to tune the guitar but also small enough to fit on a guitar headstock. As the design for the physical system began to shape up the synthesis of the project took place. During this phase the schematics were created, the PCB was designed and much of the code was written on a development board. Once the PCB arrived from the fabrication house it was populated and the code was transferred from the development board to the project PCB. Different functions were turned on one at a time and tested. While this was taking place the construction of the packaging was taking place. Once all of the components were installed in the guitar the testing phase began. There were several bugs in the design that needed to be fixed. After many small tweaks to the design, the project was evaluated based on the objectives created at the beginning of the development process. All objectives were successfully achieved and the project was deemed an overall success.

(e) Summary of how realistic design constraints were incorporated into the project (consideration of most of the following is required: economic, environmental, ethical, health & safety, social, political, sustainability, and manufacturability constraints).

Economic: Self-tuning guitars on the market today are around $3000 or more. This self-tuning guitar, with its revolutionary design and packaging, could easily be sold for less than $1000 with the manufacture and marketer receiving a profit.

Environmental: With today's society having an extreme focus on all new products being environmental friendly, it is important that this product be environmental friendly both for the future health of our planet and so that it will sell in today's market. During the manufacturing process, RoSH certified materials will be required. The casings will also be made out of recyclable materials such as ABS plastic and aluminum. During normal use, the product is expected to consume many AAA and 9-volt batteries. Either alkaline or rechargeable batteries will most be selected for use by the user. Alkaline batteries (made by Energizer or Duracell) are designed to be disposable. According to Energizer, "alkaline batteries … (have) been manufactured free of added mercury since the mid 1990s." This allows them to be, according to Duracell, "safely disposed of with normal household waste." Finally, disposal of the self-tuning guitar product is as simple as taking the product to the local electrics recycling center. There, its components will be stripped for use in future products.

Health & Safety: The primary safety concern addressed in the design of the self-tuning guitar was strings breaking and injuring the user or others. The motors used are powerful enough to break a few of the strings should they tightened too much. Limitations on how much the strings can turn per tune were added to the software of the project. The user would then easily notice if the strings are being turned too tightly while tuning.

Sustainability: The main sustainability issues are batteries, motors, and strings. Battery replacement is simple and the user can choose which batteries they use for operation. Rechargeable batteries are recommended since they are easy to recharge and since this product may be used very often, the ability to recharge the batteries would be extremely

useful. The tuning motors are easy to replace should one fail. Strings break on all guitars depending on how often they are used, and guitar players are commonly replacing strings. The self-tuning guitar makes it easy for the user to replace the strings!

Manufacturability: There is only one manufacturing constraint of the self-tuning guitar which was encountered which would need to be changed if the product was taken to a mass-production environment. The motors used to turn the tuning machines need to be modified for continuous rotation. This creates a major delay in the construction time of the project. If the project was to be mass-produced, motors would need to be found with similar form factor and continuous rotation.

(f) Description of the multidisciplinary nature of the project.

Several different multidisciplinary skills were used in the creation of the auto tuning guitar. The main focus was of course on the electrical and computer engineering to design and create the circuit and the programming necessary for functionality. This project also had a large emphasis on mechanical engineering. From the modification of the stock guitar to allow the addition of the necessary internal circuitry, to the placement and attachment of the servos to the tuning machines, these skills were invaluable in the completion of the project. In order for the correct and timely completion of homework and assignments, management and writing skills were also necessary.

(g) Description of project deliverables and their final status.

The final deliverables consists of functional self tuning guitar prototype and software. The guitar is a Squire Stratocaster that was modified to allow for the self tuning functions. A compartment was hollowed out to allow for the necessary space for the control circuitry and batteries. Modified continuous rotation servos were attached to the tuning machines at the head of the guitar to allow the change of tension of each string. An LCD screen was added to the pick guard and an existing tone potentiometer was replaced with a rotary pulse encoder to allow user navigation of the system menu. The software to control the operation has been written and provides correct functionality for all functions.

Purdue ECE Senior Design Semester Report

Course Number and Title	ECE 477 *Digital Systems Senior Design Project*
Semester / Year	Fall 2009
Advisors	Prof. Meyer and Dr. Johnson
Team Number	7
Project Title	Flying Bits

Senior Design Students – Team Composition			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Eric Glover	EE	Software	May 2010
Russell Willmot	EE	Wireless Communication/Software/RF	December 2009
Shaun Greene	EE	Power Electronics/Hardware/Software	May 2010
Steve Andre	EE	Packaging/Mechanical Design	December 2009

Project Description: Provide a brief (two or more page) technical description of the design project, as outlined below:

(a) Summary of the project, including customer, purpose, specifications, and a summary of the approach.

The Flying Bits project is an electronic display device that uses a single column of rotating LEDs turned on and off at specific time intervals utilizing the phenomenon of persistence of vision to create the illusion of a stationary image floating in the air. The project has the capabilities to project an image in a specified direction, update the image while in operation, allow a user to select a desired image to be displayed, and the capability of displaying short animations.

The purpose of the project is to create a unique, eye catching display based on the theory of persistence of vision. The device is designed for both recreational and professional use. The device can be used as a fun addition to any household to display images in a creative way. Professionally, the project can be used to display company logos, or serve as an inviting and attention catching display in any store shop window.

(b) Description of how the project built upon the knowledge and skills acquired in earlier ECE coursework.

Knowledge from previous ECE coursework was used extensively throughout the semester in the design and implementation of the project. Key course knowledge from ECE 270 and 362 was used in designing the digital system. Knowledge from ECE 433 (Power Electronics)

was found to be very useful in the power supply design. Key principals and concepts from classical physics were used in implementing a stable rotating mechanical system. Knowledge from ECE 311 and ECE 441 were used in the design of the RF portion of the project. The design of the closed loop control system for the switching power supply required us to recall a lot of what we had learned in ECE 382. Even techniques from ECE 201 were used to properly select current-limiting resistors. Skills such as teamwork and communication that were obtained from numerous projects in previous ECE coursework were used frequently throughout the semester to effectively complete the project as a team.

(c) Description of what new technical knowledge and skills, if any, were acquired in doing the project.

The Flying Bits acquired a wide variety of new technology knowledge and skills. Our team was extremely inexperienced with PCB design, therefore the team learned an extensive amount regarding this topic. The team also gained experience with debugging circuits. When implementing the persistence of vision machine, there were debug problems with the power supply, digital logic, and software (such as the initialization of a microcontroller none of us had used before, understanding the speed limitations of the different ICs used, etc.). The team became skilled at logically finding the root cause of problems, and finding solutions to solve them. The team also gained experience with soldering surface mount parts.

(d) Description of how the engineering design process was incorporated into the project. Reference must be made to the following fundamental steps of the design process: establishment of objectives and criteria, analysis, synthesis, construction, testing, and evaluation.

The Flying Bits team implemented the “Top-Down, Bottom-Up,” design approach. The overall system block diagram was the first thing designed. This design was used to develop the project specific success criteria (PSSCs). The PSSCs were used to gauge a successful completion of the project. A key aspect of the project involved the timing of the data sent to the LED post and making sure to turn the LEDs on and off at appropriate times. Data was also sent via a wireless transceiver. A thorough timing analysis was completed to ensure that the part selection was adequate to fulfill the design requirements. Ideas for how to implement each part of the design were brainstormed and carefully considered before making final decisions. With the timing analysis and PSSCs in mind, parts were analyzed and compared before selecting which parts would be the best fit. Parts were also selected to be durable and readily available in the case a part breaks and needs replacing. The project was modularized into a stationary module and a rotating module. The rotating module was powered by the stationary module via slip rings, while data was sent to the rotating module wirelessly from the stationary module. After the project was modularized, the schematics and PCB layouts were created with the success criteria and testing in mind. Debugging and testing headers were implemented on most of the key parts to allow easy access to the pins. The power supply was the first key system to be constructed and tested.

The voltage regulators and the related components were the first items to be soldered onto the board and tested. Once the power supply was tested, the microcontrollers could be added to the boards to begin testing software. A heartbeat program was written to ensure the microcontroller was properly functioning. Communication modules were then tested by sending data to status LEDs that were used to debug the software. Once the communication modules were functioning, data was sent from a microcontroller to the LED post. When this was functioning, the system was pieced together to test the overall functionality of the device. A successful persisted image was eventually achieved. The rotating module and stationary module were then brought together to send data to change the display via the wireless transceiver. After this was achieved, all of the hardware functionality was successfully achieved, and the remaining portion of the project involved software. The software was tweaked with the project success criteria in mind.

(e) Summary of how realistic design constraints were incorporated into the project (consideration of most of the following is required: economic, environmental, ethical, health & safety, social, political, sustainability, and manufacturability constraints).

Environmental: The environmental impact of The Flying Bits persistence of vision machine is extremely limited. Essentially the only concern is proper disposal of the PCBs since leaded solder was used. The acrylic disc is also hazardous to the environment. Many hazardous materials are needed when making acrylic, however for large scale manufacturing, the acrylic could be replaced by another material, and leadless solder could be used to connect the components.

Health & Safety: Health and Safety of the user of The Flying Bits is a big issue for the project. Since the acrylic disc is spinning at a rate above 600 rpm, there is a potential for parts of the LED post, upper board PCB, or one of the balancing bolts to come loose and fly off. This presents an extreme danger to a user or a person standing near the device. While all of the parts are securely fastened to the acrylic disc, a safety shield should be implemented for future revisions of the project.

Social: The Flying Bits provides a fun device that can be used in a social or professional setting. People can use the device to entertain their family or friends. Businesses can use the device as a creative way to display their company logo, while a small business can use the device in there window as a creative display sign.

Political: The Flying Bits is not expected to have any political impact.

Sustainability: Due to the fact that The Flying Bits implements many moving parts, the life of the device is expected to be short due to the likelihood of mechanical failures. Proper ventilation of the inside of the box is important to keep the motor cool. If a user does not provide adequate ventilation, the life of the device can be extremely short.

Manufacturability: The Flying Bits is extremely manufacturable. The motor used to rotate the acrylic disc is a very inexpensive box fan motor. The slip ring assembly is a collection of

stock hardware and customized carbon brush holders that could potentially be made on a large scale. The PCBs are generally simple, and the parts used are generally high stock items. The packaging and user interface are extremely simple, therefore reproducing the project on a large scale is a very feasible possibility.

(f) Description of the multidisciplinary nature of the project.

The Flying Bits persistence of vision machine is extremely multidisciplinary in nature. Both electrical and mechanical engineering were important in the design of the project. The project requires use of many moving parts, therefore there were many mechanical challenges involved. Transferring power via slip rings was a large hurdle, since it was critical to be able to provide power to the rotating unit. The spinning disc was mechanically challenging since it needed to be balanced and securely mounted on the shaft. A thrust bearing also was needed to be implemented to spare the motor bearing from the axial load.

(g) Description of project deliverables and their final status.

PSSC #1: An ability to display a pattern with moving LEDs.
Status: Complete (Demonstrated 12/9/09)
PSSC #2: An ability to control the direction in which the pattern is being projected.
Status: Complete (Demonstrated 12/9/09)
PSSC #3: An ability to display a short animation consisting of more than one still frame
Status: Complete (Demonstrated 12/11/09)
PSSC #4: An ability to update a projected image while the machine is in operation
Status: Complete (Demonstrated 12/9/09)
PSSC #5: An ability to accept user-generated input to change the display
Status: Complete (Demonstrated 12/9/09)

All of the project specific success criteria were successfully demonstrated. The desired functionality of the project was completely fulfilled.

Purdue ECE Senior Design Semester Report

Course Number and Title	ECE 477 *Digital Systems Senior Design Project*
Semester / Year	Fall 2009
Advisors	Prof. Meyer and Dr. Johnson
Team Number	8
Project Title	RCD Laser System

Senior Design Students – Team Composition			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Ryan Scott	EE	Hardware Integration	Fall 2009
Corey Lane	EE	Lasers, Processing programming language	Fall 2009
Daniel Barjum	EE	Lasers, PCB design	Spring 2010

Project Description: Provide a brief (two or more page) technical description of the design project, as outlined below:

(a) Summary of the project, including customer, purpose, specifications, and a summary of the approach.

The RCD Laser System allows a user to draw on a projector using a laser pointer. The purpose of the system is to allow annotation of presentations or other screen content, and as such its primary customer's would be educational institutions and businesses that would want to use the technology in meetings. RCD consists of two modules – the wireless camera module powered by a lithium-ion battery running a PIC18 microcontroller and the computer module which is a small single-board Intel Atom-powered PC running Windows XP. The two boxes are connected via a Bluetooth connection.

(b) Description of how the project built upon the knowledge and skills acquired in earlier ECE coursework.

This project built significantly on the skills that we had all acquired going through ECE 270 and ECE 362. Without experiencing ECE 362, none of us would have had the system integration ability or knowledge of microcontrollers required to complete RCD. ECE 362's modules regarding the details of microcontrollers were important for us to understand when choosing a new platform to work with (PIC18).

(c) Description of what new technical knowledge and skills, if any, were acquired in doing the project.

From beginning to end, we were faced with and had to overcome challenges with hardware, software, power, integration, and reliability; as a result, we learned about every piece of technology in our project. We learned and are now comfortable with: Bluetooth, the PixArt Camera, PIC18 microcontrollers, lithium-ion batteries, and the Processing programming language.

(d) Description of how the engineering design process was incorporated into the project. Reference must be made to the following fundamental steps of the design process: establishment of objectives and criteria, analysis, synthesis, construction, testing, and evaluation.

Brainstorming at the beginning of the semester to submit our project idea laid the framework to what is now the RCD Laser System. After our idea, we started finding the parts that would work optimally. After finding parts, we drew up our schematic and PCB and had the PCB fabricated. When it came in we tested our parts for fit, and implemented our design. After our initial implementation of parts and software, and hundreds of hours of troubleshooting and refining, our system was functional. After we had a functional system we refined further for reliability until the system would work for hours and hours at a time. We were then ready for our final PSSC check off and evaluation.

(e) Summary of how realistic design constraints were incorporated into the project (consideration of <u>most</u> of the following is required: economic, environmental, ethical, health & safety, social, political, sustainability, and manufacturability constraints).

Economic: Low cost high quality components were taken into consideration for use in our system. There were a few components donated to the group which brought down costs quite dramatically. Some components were bought at a higher price due to time constraints, proper planning would reduce these costs. The overall cost of the project is feasible, and mass production of the project would significantly lower the overall cost.

Environmental: The environment was taken into consideration when purchasing materials for the project. The packaging which is ABS plastic is recyclable and the Li-ion battery powering the camera is non-hazardous to the environment. The printed circuit board does contain traces of lead, there was no choice in the matter as the board was being donated to the group. There are places which take in printed circuit boards and strip the board for parts; this is a good way to reuse the parts instead of disposing of them.

Ethical: The RCD Laser System does not pose any ethical issues unless mishandled. The system does not pose any threats to a person's safety, beliefs and ideals. If mishandled the RCD Laser System could be used, like any other method of communication, to present offensive material. People could use it to draw offensive pictures or words, but this is a users fault and the RCD Laser System is not responsible in any way for user behavior.

Health & Safety: Safety was an important concern to our group. Inherently, the RCD Laser System poses little threat to a user. One of the more dangerous components of the system is the Li-Ion battery which if mishandled can leak or explode. Safety precautions were taken into account such as proper enclosure and monitoring systems for charging and discharging of battery. It is important for users to be aware of the dangers of lasers as our device requires a laser for operation. Proper labels and cautions were placed on the user manual of the RCD Laser System.

Social: The RCD Laser System was designed with the purpose of aiding in presentations whether they are in a classroom, job, or any other similar setting. The system can also be used for entertainment purposes such as drawing on surfaces in a form which is non-destructive.

Political: The RCD Laser System does not represent any political ideals or issues. The system could potentially be used by a user to promote ideals. Promoting political ideals is not a goal of the RCD Laser System and it assumes no responsibility for user's actions.

Sustainability: The RCD Laser System does not produce any destructive or constructive means in regards to the sustainability of the environment. The materials that encompass the system can be recycled and/or reused.

Manufacturability: The RCD Laser System can be manufactured and mass produced. The software can easily be redistributed and the hardware can be manufactured at large quantities. There are virtually no manufacturing constraints. All the components used in the system are available in the current market. There are several companies that manufacture similar parts used in the system which allows for changes in the system if needed.

(f) Description of the multidisciplinary nature of the project.

The main discipline practiced in our project was digital hardware design. As electrical engineers, we had the most experience with this aspect. Additionally, a lot of software development was needed. We aren't as familiar with software design as hardware. This took a lot of research since we hadn't ever programmed a microcontroller in C or programmed applications that were graphic intensive. Working with a camera that detected infrared was a new area for us as well. Finally, we had to construct an enclosure out of ABS plastic.

(g) Description of project deliverables and their final status.

We were able to deliver a complete system that included two subsystems. Subsystem one is the PCB which interfaced the Pixart Camera, the PIC18, and the Bluetooth modem. Subsystem two is the Atom board which had the software to receive Bluetooth data from subsystem one and use it to trace out the laser on the screen. All of the Project Specific Success Criteria were met. These included captures a laser's coordinates with a camera,

using the coordinates to trace out the laser on a projector screen, manipulated the color and size of the trace, clearing the screen, and making the program transparent. Furthermore, we added functionality to make stamps, save and load images, erase, and change background colors. Our shortcomings are that we weren't fully able to the RF transmitter function and the battery fuel gauge.

Purdue ECE Senior Design Semester Report

Course Number and Title	ECE 477 *Digital Systems Senior Design Project*
Semester / Year	Fall 2009
Advisors	Prof. Meyer and Dr. Johnson
Team Number	9
Project Title	DART

Senior Design Students – Team Composition			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Jacob Pfister	EE	PCB Design, Hardware	Spring 2010
Michael Phillips	CompE	Software, Hardware	Spring 2010
Josh Piron	CompE	Software Development	Spring 2010
Kevin Templar	CompE	Software Development	Spring 2010

Project Description: Provide a brief (two or more page) technical description of the design project, as outlined below:

(a) Summary of the project, including customer, purpose, specifications, and a summary of the approach.

The Driver's Assistant Recorder and Tracker (DART) is a speedometer, a stop watch, an accelerometer, a temperature sensor, and a lap counter. The DART was built for the go-kart enthusiast who is looking to improve their race performance. The DART is able to achieve this purpose by logging race data that can later be analyzed by the driver to help them achieve an optimal level of performance. The DART screen is highly customizable and allows the customer to choose which information to display as well as where to display it. The DART also gives the customer the option of whether or not to log data. If data is logged then it is stored onto a removable SD/MMC card in a text file. The format of this text file allows for most spreadsheet programs to import the data so that it may be fully analyzed. All features of the DART are available for use during practice laps or solo go-kart racing. The DART was implemented using a variety of sensors, which were installed at various locations around a go-kart. The DART then monitors, converts, and logs these sensors using a central microcontroller. The team was able to achieve full functionality in accordance to the project specific success criteria that were set at the beginning of the semester.

(b) Description of how the project built upon the knowledge and skills acquired in earlier ECE coursework.

The project started with experience from reading datasheets. These skills started in ECE 270 and were built on in ECE 362. Basic part selection, such as resistor and transistors, were parts of ECE 207, 208, and 255. The variety of assembly and C programming skills

used when programming microcontrollers were all developed in ECE 264 and 362. Circuit and PCB design were also developed in ECE 270 and ECE 255 with use of OrCAD. Experience with OrCAD helped learning the PADs program that was used to design the PCB.

(c) Description of what new technical knowledge and skills, if any, were acquired in doing the project.

Several important technical skills were acquired during this project. From a hardware perspective, the basics of PCB design, including noise minimization, analog and digital signal separation, bypass capacitor placement, trace width determination, and part selection techniques, were among the most important. A fundamental understanding of the PADS Logic, Layout, and Router software tools was also gained in this process. Power supply design experience, including knowledge of the different types of voltage regulators—linear dropout and switching—was also very useful. Finally, the extensive experience in soldering surface mount components led to the development of this practical skill. From a software perspective, experience with a microcontroller development suite, including software and a development board, developed this important, industry-related skill. Knowledge and experience of the complexities of debugging software running on custom hardware was also worthwhile.

(d) Description of how the engineering design process was incorporated into the project. Reference must be made to the following fundamental steps of the design process: establishment of objectives and criteria, analysis, synthesis, construction, testing, and evaluation.

The engineering design process that brought the DART to life is as follows. During the establishment of objectives and criteria phase the team came to an agreement on what project to pursue. It was also during this time that the team established the project specific success criteria which were used at the end of the semester to measure the functionality of the DART. During the analysis and synthesis phases the team decided which components to use and formulated a block diagram for the DART. From the block diagram the team then generated a schematic and PCB layout. During this same time much of the software was developed using a development kit. When the PCB arrived from the fabrication house the team began the construction and testing phases by first putting on the power components onto the PCB and then tested those for functionality. Then the team incorporated the microcontroller and again tested for functionality. From there the team interfaced one sensor at a time testing after each one was put on the board. After all was done the team entered the evaluation phase and wrote a final report the mentions some of the changes we would have liked to make if we were going to repeat the design process for a version two of the DART.

(e) Summary of how realistic design constraints were incorporated into the project (consideration of <u>most</u> of the following is required: economic, environmental, ethical, health & safety, social, political, sustainability, and manufacturability constraints).

Economic: Since the project was self funded, the desire to keep costs down were even greater than if it had been developed by any company. With the current economic state of the country, this constraint was made even more realistic. From a production perspective, the cost was in a higher range than could be expected for manufacture, but from a prototyping perspective, the cost was much less than a company would dedicate for a new product.

Environmental: There were few to no environmental constraints for this project. The issue of disposal is outline in the user manual, especially in regard to the battery. Other environmental issues were not considered.

Ethical: There were no ethical constraints for this project.

Health & Safety: Health and Safety constraints came in two general areas: proper instillation and damage concerns. The first, proper instillation, was confronted to the best of the abilities of the team. Outlining sensor and HUD installation was handled in the user manual. Possible battery or LCD damage was the main areas of health concerns and these were also confronted in the user manual.

Social: There were no social constraints for this project.

Political: There were no political constraints for this project.

Sustainability: A desire through the design and assembly of this project was to ensure sustainability. These constraints were both self and academically imposed. Even outside of academia, the team enforced constraints of sustainability attempting to create a very viable product.

Manufacturability: Manufacturing constraints were primarily for the PCB design. A few parts were deemed impractical due to the lack of unadventurous methods to solder them onto the PCB. Other manufacturing constraints came from obvious economic restraints.

(f) Description of the multidisciplinary nature of the project.

The multidisciplinary nature of the project was total from the start. The obvious disciplines of Computer Engineering and Electrical Engineering outlined many project steps. The PCB design started with part selection--a step that required both Computer and Electrical Engineering skills. The PCB design then required learning the PADs program which is a skill that could be linked to Computer Engineering or just Engineering in general. The software design and writing aspect of the project included C programming skills from the Computer Engineering discipline. Once the hardware was assembled and the software burned, the debugging came from both Computer and Electrical Engineering skills. Outside of Electrical and Computer Engineering disciplines, skills in English, time management, and team management were also crucial throughout the process.

(g) Description of project deliverables and their final status.

DART includes a main box which is mounted on to a go-kart steering wheel. Peripherals including a battery charger, an accelerometer, a lap counting IR sensor, a speed sensor, and a temperature sensor are also included and connect directly to the main box. All of the sensors are able to be read to a high degree of accuracy for both display and storage to an SD card. The battery charger connector plugs into a wall outlet and charges the internal battery that is stored in the main box or can power DART itself if the battery is not operational for any reason. The interface of the box includes a graphical LCD, two LEDs, and four pushbuttons. The pushbuttons allow navigation of the menus on the LCD. The LEDs warn of low battery and of an engine temperature above set maximum. All of these features are final and working with few minor bugs such as a few drawing glitches that do not impact usability. To accompany this there is a final report detailing everything done, a user manual, and a project website containing all development information.

Purdue ECE Senior Design Semester Report

Course Number and Title	ECE 477 *Digital Systems Senior Design Project*
Semester / Year	Fall 2009
Advisors	Prof. Meyer and Dr. Johnson
Team Number	10
Project Title	E.D.L.E.T. (Extensible Digital Logic Education Tool)

Senior Design Students – Team Composition			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Michael Gasser	CmpE	Hardware/Firmware	May 2010
Ben Parsons	CmpE	Software /PCB	December 2010
Joe Leong	CmpE	Software/PCB	December 2010

Project Description: Provide a brief (two or more page) technical description of the design project, as outlined below:

(a) Summary of the project, including customer, purpose, specifications, and a summary of the approach.

This project is a digital logic educational tool. It provides a highly configurable game play framework that omits a small piece of digital logic. A student designs this logic and implements it on a solder-less breadboard. Thus with only a beginner's knowledge of digital design a student can create a fully functional game. This project was conceived after a prototype version experienced great success as an outreach tool for ECE over the summer of 2009 with Purdue University Minority Engineering Program (MEP) and Women In Engineering Program (WIEP).

The project was accomplished using a microcontroller whose I/O functionality is controlled by a host. The host provides a suite for graphically altering the game play experience. A USB link between the host and microcontroller allowed for quick communication across a ubiquitous protocol. Protection circuitry was provided for the microcontroller I/O pins. By controlling the microcontroller and reading back inputs from it, a full game play experience was realized. Emulated commercial video games packaged with the product include Dance Dance Revolution and Guitar Hero. Additionally, the hardware necessary for these games (Dance Pad, Guitar) was provided.

(b) Description of how the project built upon the knowledge and skills acquired in earlier ECE coursework.

Minimally, knowledge of digital logic from ECE 270 was necessary as it was our goal to interface with similar circuits. Additionally we required knowledge of embedded systems and how to design software for them. This knowledge is very similar to that which is acquired in ECE 362. Basic analog circuit design was also utilized for this project, a skill taught in ECE 255. Both the host and microcontroller leverage the use of efficient algorithms and data structures, particularly the host, which employs numerous hash tables, queues, and custom data structures. Additionally the host is written as a fully object oriented program to accommodate for code maintainability. These skills were acquired in ECE 264, ECE 368 and ECE 462. In general our project broadly encompassed the computer engineering curriculum.

(c) Description of what new technical knowledge and skills, if any, were acquired in doing the project.

New knowledge was acquired in several different areas. The use of USB was new to the entire team as well as much of the graphical front end programming. Additionally, the use of threads and event listeners in java eclipsed our previous knowledge on both subjects. This is the largest software project anyone on the team had ever built from the ground up and the design process was educational.

All aspects of the hardware design and implementation process were essentially new to us. The PCB layout and fabrication in particular as well as power supply design both provided an ample share of surprises and learning experiences.

(d) Description of how the engineering design process was incorporated into the project. Reference must be made to the following fundamental steps of the design process: establishment of objectives and criteria, analysis, synthesis, construction, testing, and evaluation.

The engineering design process in this project had a very clean flow. Hardware and software design were largely separate, but followed similar design considerations and steps. Initially we formed objectives and criteria based on previous experience with outreach projects over the summer. This led us to the need for a broad and configurable product that was robust and durable. We decided on the use of USB because it is present in all computers and well documented. Additionally, we decided to pursue both Dance Dance Revolution and Guitar Hero as adapted platforms because of their commercial success and appeal to today's youth. Our preliminary design was carefully analyzed for usability, safety, and durability. We purchased PDIP versions of most of our parts and prototyped some of the analog circuitry before committing to a final design plan. Once a final design had been chosen, we laid out the parts on a PCB and had the PCB manufactured. This validated our choice to purchase PDIP versions of out parts. The first PCB came back unusable due to our

errors, but development was not drastically delayed. We corrected the mistakes and purchased a second PCB. Construction of the PCB took a fairly typical course, with logical blocks of the circuit being laid out and tested individually before more part placement was done. The synthesis of these parts, the firmware, and frontend software happened over the course of several weeks and included many minor changes to logical flow of software. In the end, the product worked almost exactly as we intended with only a few minor differences. It is very close to our original conception and works in every way we want it to. In final evaluation, we would do this project very similarly if we had to do it again.

(e) Summary of how realistic design constraints were incorporated into the project (consideration of most of the following is required: economic, environmental, ethical, health & safety, social, political, sustainability, and manufacturability constraints).

Economic: E.D.L.E.T. has the potential to affect the economy in a positive way. Training more engineers adds value to the economy and has the potential to advance the quality of life for the entire world. This project is intended to be used as an outreach project to draw students into engineering. As the global market continues to evolve, educating more engineers can only be a good thing.

Environmental: This project uses a PCB manufactured with very few harmful chemicals, specifically, no lead, mercury, or arsenic. Parts were chosen for this project with environmental impact in mind. Most all of the parts are ROHS compliant. Recycling instructions for the final product were provided as well.

Ethical: Two ethical issues dominate this project. First, the need for safety, which is a primary concern because we are providing a development board with exposed power and ground terminals to students. The project took great care to outline safety instructions in the user manual and to make students aware of potential safety hazards. Additionally, this project has a large social impact as it is intended for use as an outreach tool by Electrical and Computer Engineering. There is a large need for engineers and this project is an attempt to help deal with that.

Health & Safety: This project has limited ability to cause harm as far as health or safety are concerned. It can potentially be misused and cause electrical shorts or fires but it is doubtful that the maximum voltage of unregulated 7.5 V coming into the project will be enough to cause harm. The project is fused with a 1A fuse to combat the eventuality of a student shorting power and ground.

Social: This project has broad reaching social implications. It is designed to benefit society by attracting students to ECE. This is a noble profession that is typically associated with making the world a better place. This project aims to encourage that.

Political: Increasing educational standards is a recurring political theme regardless of party lines. This project encourages education, which can only be viewed as a good thing from a political viewpoint.

Sustainability: The limit on the sustainability of our product is mainly the amount of abuse it will take from students during routine use. We anticipate this will affect product lifetime more so than any parts failing due to typical lifetime limits of electronic components.

Manufacturability: This project is easily extendable to mass production but the nature of the project makes production at a very large scale mostly irrelevant. The target market for E.D.L.E.T. is a very small group of Universities and other technologically related groups such as the Purdue University Women In Engineering Group, who successfully used an E.D.L.E.T. prototype as an outreach tool in the summer of 2009. Specific manufacturing concerns include the availability of the parts included on E.D.L.E.T. and the need for a more ergonomic packaging. These may become issues at a large scale production.

(f) Description of the multidisciplinary nature of the project.

This project was multidisciplinary in the sense that it required knowledge of hardware, embedded software, higher level software, and physical construction of electrical equipment. These distinct aspects, while all encompassed by the discipline of computer engineering still require specialization such that if the project were carried out on a larger or more complicated scale many disciplines would need to be involved. A mechanical engineer would be necessary for the construction aspect of the project, a computer scientist for much of the software, and an electrical engineer for the hardware. Additionally, a patent lawyer, an expert on public policy, as well as a lawyer to handle safety and liability would be necessary.

(g) Description of project deliverables and their final status.

Our project delivered on the following specific success criteria: (1) An ability to generate inputs to a digital scoring circuit that a student constructs and read output from that circuit; (2) An ability to display custom, game play configurable graphics on an external monitor; (3) An ability to read and interpret files, stored in the system, that specify graphical and audio game play features; (4) An ability to control micro controller I/O functionality from the embedded host; (5) An ability to allow definition of multi-player games.

All of these goals were achieved and demonstrated to course staff in the second to last week of the project timeline. (1) was demonstrated by constructing the digital scoring circuit for both the adaptation of Guitar Hero and Dance Dance Revolution. (2) was demonstrated by using the Java Lightweight Gaming engine to create graphics from the host. (3) was demonstrated by parsing and interpreting XML files that defined games. (4) was demonstrated through a specific packet definition that will raise or lower voltages on micro controller pins and allow digital inputs to be read from microcontroller pins. (5) was demonstrated through the definition and demonstration of a multi-player game.